THE BEAMA JOURNAL

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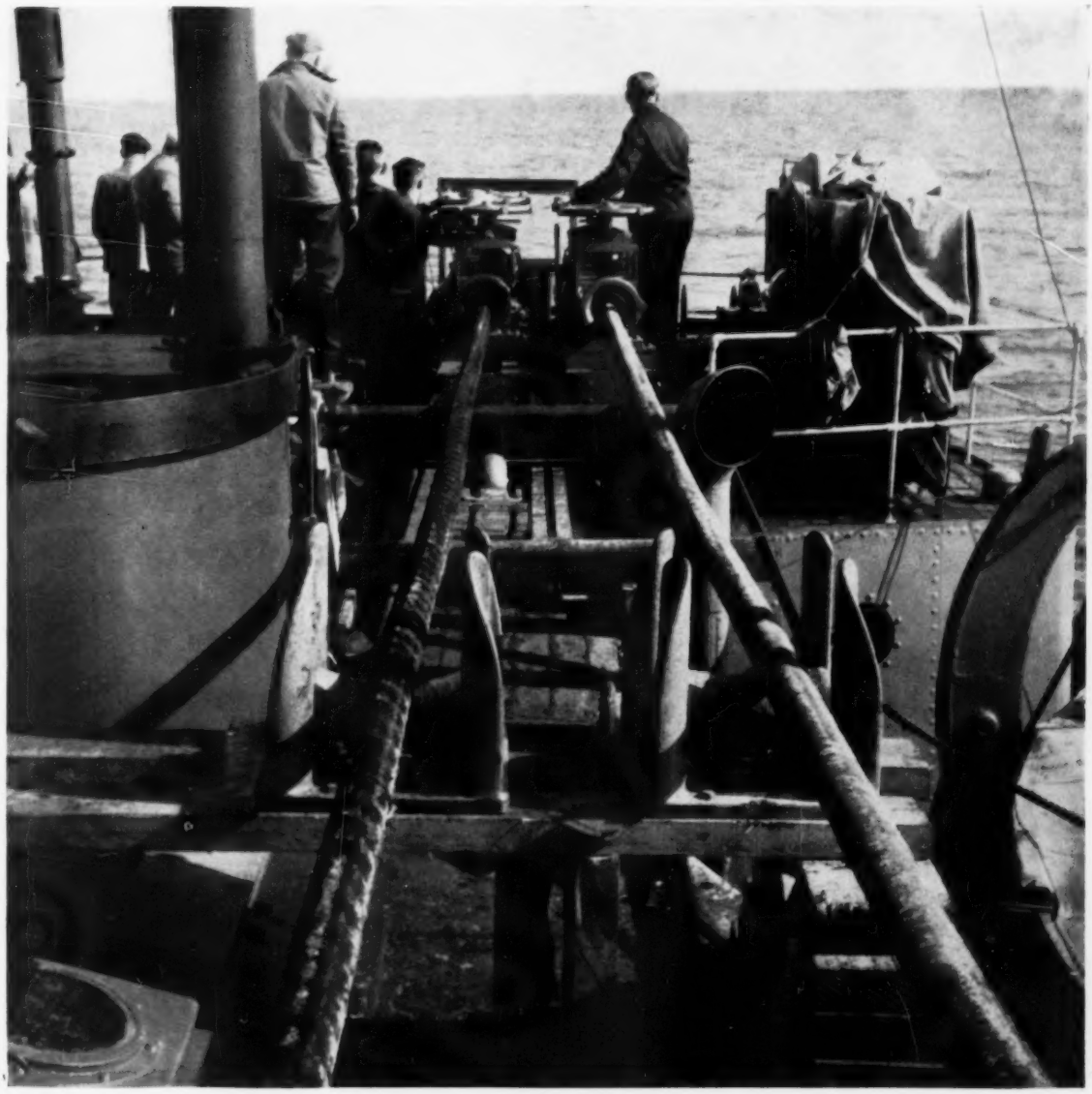

Laying the Cross-Channel Power Cable

A QUARTERLY REVIEW OF

BRITISH ELECTRICAL AND ALLIED ENGINEERING

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Cover Illustration. *The motor vessel* Dame Caroline Haslett *laying the two cables of the British half of the cross-Channel power link. The project, now completed, will come into operation towards the end of this year, bringing to reality an idea first suggested* 40 *years ago*

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A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

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Future Screw-Thread Practice in the Electrical Industry

In 1958 The BEAMA issued a statement reiterating its policy and expanding its reasons why British Whitworth and BA threads should continue to be used as the standard production practice of the British electrical industry.*

This was based on the fact that the International Standards Organisation had been unable to obtain agreement on one recommended future world practice and was proposing to issue two recommendations of equal status—one on inch system (the Unified Inch Thread), and the other a metric system (The Unified Metric Thread).

The 1958 statement of BEAMA policy included the following three paragraphs:

(i) 'When the final recommendations of the ISO become available and an assessment can be made as to which of the two recommended standards is likely to be more generally acceptable than the present British standard, then will be the time for the British engineering industry to consider again the pros and cons of any change.'

(ii) 'If at that time a change appears necessary or desirable it must be planned in the interests of economy and minimum inconvenience both to the British engineering industry and those it serves at home and abroad. Not to do so would cause untold inconvenience in the maintenance and extension of British equipment already installed.'

(iii) 'Consideration of the problems as they may affect only one particular production or purchasing unit must inevitably lead to unilateral and conflicting decisions, the cumulative result of which will mean that the many advantages of a standard interchangeable screw thread practice will no longer be available. What is essential is co-operative consideration of the problems as they will affect the future well-being of the industry as a whole.'

While there is, as yet, no indication that Whitworth and BA threads are now less generally acceptable at home or overseas than in the past, if and when the ISO recommendations are adopted then it must be foreseen that Whitworth and BA threads will become obsolescent as generally acceptable practice. If then a standard interchangeable production practice is to be maintained within the United Kingdom electrical and allied industries in the future, co-operative consideration of future practice is essential.

With these thoughts in mind The BEAMA Council, some six months ago, initiated an enquiry among its member-firms. It was directed towards long-term consideration of all the many relevant factors which should influence future policy. These considerations included the importance to the industry and its customers of having a common screw thread policy; the significance of exports to metric-using and to inch-using countries and likely future influences in those export markets; any existing demand for the unified inch threads, and generally an attempt to foresee the long-term trends.

The results of this enquiry show that a substantial and unmistakable majority opinion is that when the time comes to make a change, it should be to the ISO Metric Thread and that it is desirable to maintain a common normal production practice within the electrical and allied industries. This majority view is maintained when the membership is taken as a whole and when grouped as 'Heavy Plant', 'Industrial Equipment' and 'Light Engineering and Domestic Equipment'.

The reasons given by individual members were detailed in relation to their particular products and present and future markets. In particular it emerged that there is a widely held view that, when the time comes to change from Whitworth and BA threads, the adoption of another inch thread might well prove to be only an interim measure which would thus involve members—and their customers—in a duplication of the substantial costs and disturbances which any such change must entail.

In the light of this consensus of members' opinions, it is the intention of The BEAMA to initiate discussions with the major customer and trade interests with which they are concerned so as to seek to work out an acceptable long-term plan for giving effect to this screw thread policy.

* THE BEAMA JOURNAL, **65**, No 2, p 45

We have printed this important statement by The BEAMA Council in full because of its importance to buyers and users all over the world of British electrical equipment, and because we believe their long-term interests will be better served by the uniform adoption of one standard interchangeable screw thread.

Accent on Research

It happens that this issue of THE BEAMA JOURNAL contains three features devoted to research projects. One of them (page 103) is a brief review of some of the year's activities revealed at the annual open days at the National Physical Laboratory which are of particular interest to the electrical industry; activities which, although at present still in the realm of applied research, are intended to have an important influence on commercial developments in the future.

The other features are descriptions of two new research laboratories which have been officially opened during the last few months: the Nuclear Research Laboratories of the Central Electricity Generating Board (page 105), and the McFadzean Laboratories of the B I C C Group (page 97).

There is yet another important project which was made public just as this issue was going to press: the new Creep of Steel Laboratory of the Electrical Research Association. We hope to deal with the work in this important field of research in our next issue.

We said in the opening sentence that 'it happens' that research is a major topic of this issue. That is true only insofar as the events we have chronicled all came into the news within a short period of time. From any other point of view, research in the electrical industry never 'happens'; it is the carefully-planned result of a deliberate and far-sighted policy which has played an ever-increasing part in the successful development of the industry.

As Mr Stanley F. Steward, the Director of The BEAMA, pointed out in his paper to the British Electrical Power Convention this year (see pages 91 to 94 in this issue), the very nature of the electrical industry as an expanding and technically progressive industry makes large demands for capital investment and also places great emphasis on research.

The full fruits of the annual investment in research of £80 to £90 million by Britain's electrical manufacturers will be gathered in the future, since research is a never-ending pursuit of an objective with no finite limits: the ceaseless striving to make still better that which was already considered good before.

Nevertheless, the many great achievements already standing to the industry's credit are but today's fruits of yesterday's research and developments, and they deserve the world-wide recognition they have justly earned as the best in the light of today's knowledge; that they will be still better in the light of tomorrow's knowledge is the industry's assurance for its future expansion and progress.

Most of these achievements have been mentioned or described in past issues of THE BEAMA JOURNAL, but this seems to be an appropriate point in time at which to recall just a few of them.

The quite spectacular rise over the past ten years or so in the capacity and efficiency of generating plant, from the 60 MW sets regarded more or less as the standard in 1939 to the 550 MW sets now on order, leading to an increase in overall thermal efficiencies from 21·33 to 26·71 per cent, with the best station reaching a figure of 34·28 per cent.

The next step into a new phase of the story of generation is the first 375 MW supercritical sets which are now under construction, and which will lift the thermal efficiency to the 40 per cent level, with a corresponding substantial saving in fuel costs.

The story of generation also opens another new chapter with the commissioning this year of the first two of Britain's seven new stations in the 3 000 MW nuclear power programme—the first of its kind and the largest in the world.*

In the field of transmission, there is the Cross-Channel power cable (see pages 89 to 90 in this issue)—a notable triumph of cable research and Anglo-French co-operation—which will operate at the highest d c voltage yet used for power transmission: also in the near future is the uprating of the British super-grid—the largest integrated power network in the world—from 275 kV to eventually 700 kV; an impressive step which could only have been taken with confidence as a result of British research and development in insulation, cables, switchgear and transformers.

So we could go on listing many other outstanding achievements, but even if there were space enough to do so, they could only re-inforce our thesis: that research and development are the mainsprings of the British electrical industry's service to the world—yesterday, today and tomorrow.

Sir Kenneth Allen

An announcement in Her Majesty the Queen's Birthday Honours List of the conferment of a Knighthood on Mr W. Kenneth G. Allen, Chairman and Managing Director of W. H. Allen Sons & Co Ltd, Bedford, and Chairman of Gwynnes Pumps Ltd, Lincoln, has been received with much pleasure throughout the Engineering Industry.

Sir Kenneth Allen has for many years been actively associated with important bodies and associations in the industrial sphere, and is at present a member of the Councils of the British Internal Combustion Engine Manufacturers' Association (of which he is a past Chairman), and the British Engineers' Association (of which he is a past President). He also holds the office of a Counsellor of the British Electrical and Allied Manufacturers' Association (of which he was Chairman of the Council for the two years up to 1961). In addition, he is a member of the Engineering Advisory Council.

Also, at the present time, Sir Kenneth Allen is First Deputy President of the Engineering Employers' National Federation, Chairman of the Nuclear Energy Trade Associations' Conference, and the Chairman of the British National Committee of the International Congress on Combustion Engines.

* THE BEAMA JOURNAL, **68**, No 1, pp 32–37

Laminates in the Electrical Industry

Editor's Note. *The following article, which is based on a text supplied by Formica Ltd, is a brief description of the manufacturing processes operated by this firm and of some of the subsequent uses of laminates.*

SINCE the first tentative use of impregnated papers as insulating materials, great strides have been made in the technology of resin and paper manufacture, so that insulating materials based on laminated structures are today firmly established as basic insulating media in the electrical industry. One has only to look at the annual tonnage of laminated materials produced in the U K to appreciate the contribution made by these synthetic materials to industry as a whole and to the electrical engineering industry in particular. British manufacturers are using in increasing quantities laminated materials in instruments and other electrical machinery that are exported to countries all over the world. The use by a British manufacturer of laminated materials in instruments that were eventually exported to the United States and were used in the tracking of the rocket flight made by Commander Shepard is a recent example of the way in which British laminates are being used in the export field. A substantial proportion of the laminates produced in the United Kingdom is exported and used by manufacturers overseas as an essential component in their products.

To explain such widespread use it is necessary to look at the combination of properties that are offered by laminated insulating materials.

Basically, laminates consist of a number of resin-impregnated sheets stacked one on top of the other which are consolidated under heat and pressure to produce stiff homogeneous sheets. They are characterised by a reasonably constant distribution of resin throughout the filler and are thereby distinguished from resin 'sandwiches' such as plywood, in which the resin merely acts as an adhesive for bonding individual plies.

In general, the fibres of the filler are responsible for most of the strength and toughness of the laminate, while the resin phase confers chemical and water resistance and good dielectric properties. The relation between the filler and resin, and the proportions of each which are present, are of great importance and are responsible for many technical subtleties.

The main advantage of laminated plastics in the field of electrical insulation is that they effect a necessary compromise between filler and resin properties, thus providing good dielectric properties combined with adequate mechanical strength.

The wide variety of resins and fillers available, together with variations of the proportions of each used, provide a tremendous number of laminates exhibiting a wide range of properties. Unfortunately, certain properties are also extremely sensitive to minor variations in the process, with the result that while the essence of the process is simple, the production of consistent products having the optimum combination of attainable properties requires the closest possible control of all the variables at each stage of the manufacture.

The stages in the manufacture of these materials are as follows:

The main raw materials used are synthetic resins which are either purchased from resin suppliers or manufactured by the laminator from the basic raw materials: paper and other fibrous sheet materials, such as cotton, asbestos or glass fabrics, fabricated with the assorted armoury of modern industry ranging from boiler feed chemicals to tungsten carbide tipped saw blades.

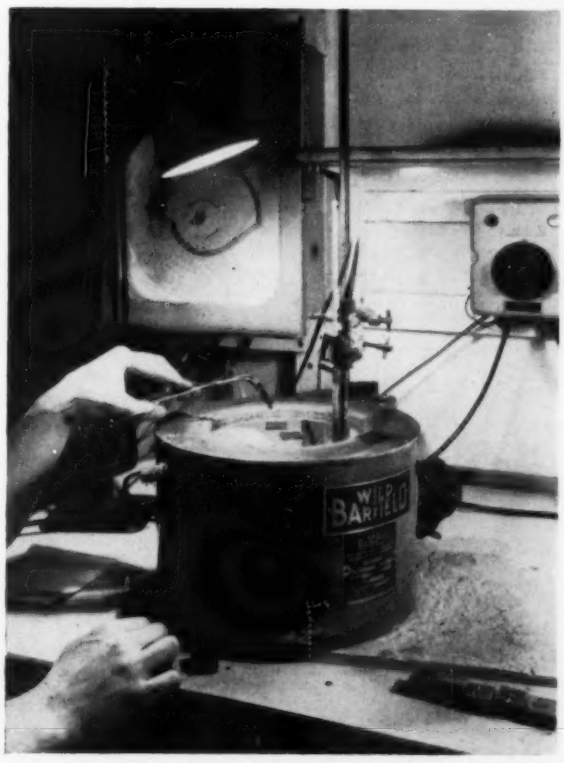
The main controls exerted over the raw materials are laboratory tests designed to ensure that those properties essential for the production of consistent products are maintained within the closest possible limits.

Resin Manufacture

It is now customary for the larger manufacturers of laminated plastics, such as Formica Ltd, to make at least the major proportion of the resins which they consume.

The manufacture of phenolic, urea and melamine formaldehyde resins for paper impregnation each follows broadly similar lines.

The stainless steel reaction vessel is double-skinned



Testing copper-clad laminates for their resistance to hot solder

to permit external heating and cooling and is of about 1 000 to 2 000 gallons (4 546 to 9 092 l) capacity. There are facilities for stirring, atmospheric and vacuum distillation and reflux, and the loading and discharge of liquid and solid charges. The reactants, such as phenol and 37 per cent formaldehyde solution, are weighed and loaded into the cold reactor together with the catalyst. The reaction is carried out by heating.

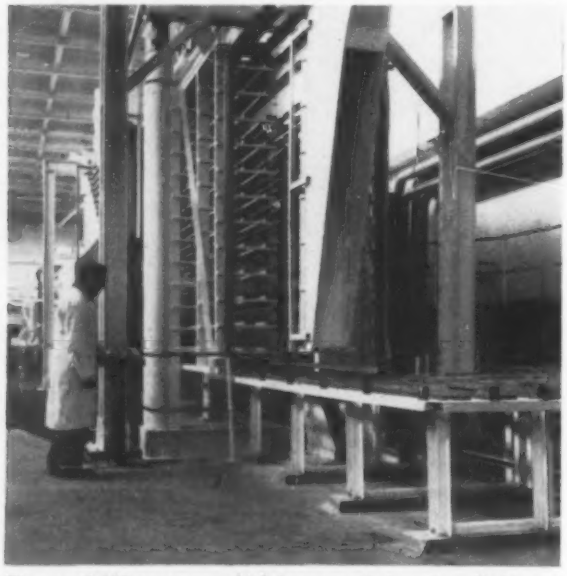
As in the case of all synthetic resins, the phenol formaldehyde resins are not pure stoicheometric compounds but a mixture of many different chemical units of widely varying molecular weights. Thus, in order to produce a consistent material—essential for subsequent processing operations—it is very important that the time/temperature history of the resin is carefully controlled.

Impregnation

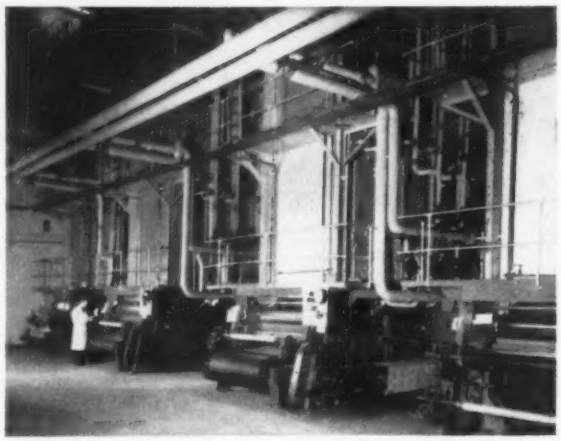
The paper or fabric is impregnated and stoved on continuous impregnation machines. The synthetic resins are reduced to the required viscosity and solids content by blending them with alcohol or water, and the continuous web of paper or fabric passes under an immersed roller in the tank of varnish and then through some form of metering device, such as a pair of 'doctor' rolls which can be adjusted to give the required varnish pick-up.

The ovens are normally of the hot air recirculation type using steam or high-pressure hot water heating batteries and with the air flows adjusted to maintain the economic ratio of fresh air to recirculated air in the system.

The properties in the treated paper which have to be closely controlled are the resin content, the volatile content and the 'flow' or degree of cure of the resin. The latter is closely connected with the volatile content but is also dependent upon the heat history of the resin, and it is generally desirable to remove as much as possible of the free volatile matter without over-heating the paper to the degree where the cure of the resin is appreciably advanced.



The new 6 100 ton press which has recently been installed in one of the Formica factories



Four of the large machines on which are treated most of the critical industrial materials manufactured in the Formica factory in the north of England, claimed to be the largest laminating plant in Europe

The size and complexity of the hydraulic press depends very much upon the grade of laminate which is being produced. Modern presses usually have 12 to 16 'daylights' or openings between the platens, which are up to 10 by 4 feet (305 by 122 cm) in size. Since the pressures used on the work are of the order of 1 ton/in^2 (1·57 kg/mm^2) the total pressure exerted can be as great as 6 000 tons (6 096 000 kg).

In the interests of economy it is necessary to press as many boards as possible in each press load, and this is achieved by having automatic loading and unloading equipment to enable the whole press load to be changed simultaneously, and by having the maximum number of boards in each 'daylight'. By this means it is normal to produce about 100 boards in one press cycle of about 1½ hours. The consistency of properties and visual appearance depend very much upon each board receiving a closely similar time/temperature treatment.

Quality Control

The whole question of process and quality control of laminates is extraordinarily interesting, but will not be discussed in detail in this paper. The customer very rightly demands that every square inch of material that he buys shall be fully up to standard and consistent in its properties and appearance, since the failure of a piece of laminated plastics costing a fraction of a penny can in certain circumstances cause serious damage.

This consistency has to be achieved in spite of the fact that most of the raw materials, much of the process, and all the products can only be controlled on a statistical basis in which the standard deviation is equally as important as the mean.

The over-riding need is the means of reducing variation of all properties to the minimum at all stages of manufacture by the increasing use of more sophisticated methods of continuous measurements. So important is the need for the closest possible control that the laminates manufacturer will advisedly adopt the view that

constancy is not merely a means to an end, but truly an end in itself.

Other than their mechanical and electrical properties, a further claim may be made for laminated plastic insulating materials. Operations such as sawing, punching, turning, milling, routing and tapping can be carried out using conventional tools; operators need no special training to handle these products.

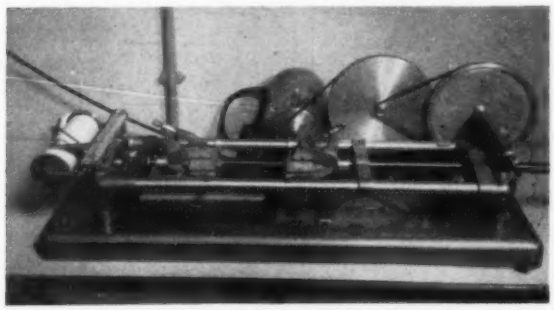
This versatility has encouraged the extensive use of laminates in the manufacture of transformers, switchgear, distributor panels, radio, television and radar equipment, electronic computers, telephone selector panels and in many other equipments.

Metal-clad Laminates

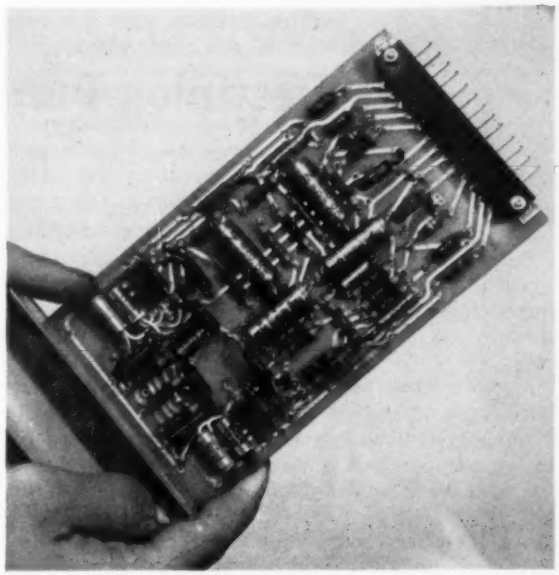
Perhaps the greatest impact on the electrical industry, in terms of laminates, has come from metal-clad laminates. It is only ten years since the commercial development of printed circuits started, yet they are now accepted and used throughout the electrical industry. In past years, electronic engineers relegated plastic materials to non-essential parts of their equipments, and the idea that these materials should form the basis of their instruments was remote from their minds. The position has now changed and, in fact, the reliability of present-day instruments depends a great deal upon the performance of metal-clad laminates.

The introduction of printed wiring and components has also brought with it economies of space and cost and has eased a large number of production problems. Automatic component insertion, dip- or wave-soldering, and almost complete standardisation of replicate circuits represent major advances in the techniques of circuit production which accrue from the use of laminated plastics. Perhaps the best example of the reliability of these laminates is their use in rockets. The American 'Vanguard' rocket which has been instrumental in placing several satellites in orbit, and the satellites themselves, have contained circuits manufactured from Formica copper-clad laminates. Nearer home, Formica industrial laminates have been used in the Bristol-Ferranti 'Bloodhound' rocket; the complex control system was based on printed circuits, since they were found to be reliable in conditions involving shock and vibration.

Another example showing the reliability and flexibility of these materials is their use in computers. The Ferranti 'Pegasus' and 'Perseus' computers use large quantities of Formica laminate for a number of reasons. A 'plug-in' panel is reliable since there is no danger of broken wires, and this type of component can be reproduced identically in unlimited numbers. This means that all the panels have identical wiring capacity and inductance and consequently identical behaviour, and this permits simple substitution of faulty panels. These are but two examples of the use of copper-clad laminates, but they are particularly significant in that the completed units are tremendously expensive and the reliability of each component is imperative.



Part of the equipment used for the mechanical testing of industrial laminates



One of the 6 000 or so printed circuit panels used in the Emidec 2 400 data processing system made by E M I Electronics Ltd

Extensive use of copper-clad laminates is also evident in the radio and television industries.

The automatic exchange typifies the manner in which laminated materials work unseen. Briefly, these materials are used as separators in banks of uniselectors and two-motion selectors and in the springset of relays, together with a large volume of insulating 'hardware'—for example, terminal strips, washers and bushes. They are also used inside the familiar telephone instrument itself. Again, reliability is the keynote, and automatic exchanges embodying laminates have been life-tested to as much as an equivalent of 80 years' service. Since this is longer than the planned life of any telephone exchange, it offers a great reserve of reliability.

Switching devices, of which there are many interesting varieties, offer considerable scope for the employment of laminates as an insulating medium. These laminates are found no less frequently in the miniature relays for electronic applications than in the large circuit-breakers for heavy-duty installations.

This article, albeit limited, has been an attempt to describe the manufacture and some of the uses of laminated plastics as insulating materials, and in doing so show that they are no longer novelties but have gained a respectability of their own. The variety of scientific achievement is increasing and the laminator cannot afford to ignore modern practices; he must—and will—keep pace with industrial development.

The Ffestiniog Pumped Storage Scheme

WHILE the British electrical industry has supplied hydro-electric generating equipment to many countries in the world, including some of the largest installations in existence, the opportunities for using this method of generation within the United Kingdom are limited by reason of its geography and the scarcity of suitable rivers.

In general, only the North of Scotland offers favourable conditions, and the installations built for the North of Scotland Hydro-electric Generating Board have for many years provided a valuable proving ground and served as an effective 'shop-window' where engineers and buyers from overseas could see British hydro-electric equipment in operation under service conditions.

The possibilities of pumped storage schemes have however been under investigation for some time, and these have culminated in the big project at Blaenau Ffestiniog in North Wales.* This is unique in that it is not only the first of its kind in Great Britain, but is the largest pumped storage generating plant in the world.

Work on the site began in 1957 and the first set is now due for commissioning later this year, followed by the other three sets at approximately six-monthly intervals.

This is therefore an appropriate occasion to give a general description of this very important project.

After a careful study it was decided that the most favourable conditions would be achieved by a generation period of 4 to 5 hours during the day; pumping would then be carried out during the night between midnight and 6.30 a.m. Site conditions at Ffestiniog limit the maximum storage capacity to 60 million cu ft (1.7 million m^3), which corresponds to a daily station output of about 1·2 million kWh; the maximum generating capacity was therefore limited to 300 MW, assuming a daily generating period of 4 to 5 hours.

The station will also act in a reserve capacity to meet abnormal breakdowns elsewhere in the system, since one of the features of a hydro-electric plant is that it can be started up rapidly and put on to the grid in a few minutes. This offers a marked economy, even if considered only in relation to standby fuel costs which would be necessary to maintain boiler pressures in a conventional station.

The gross annual generation is expected to be in the region of 300 million kWh with a corresponding annual load factor of 11·4 per cent. The total capital cost of the Ffestiniog scheme, including transmission, is estimated to be £15 million, compared with an estimated £25 million for an equivalent steam station. The saving in annual running costs on the same comparison should be about £207 000.

The scheme can be divided into four sections—the upper reservoir, the pressure conduit system, the power station and the lower reservoir. A surge shaft is not incorporated because of the unsuitable topography and the good head-length-ratio of the site; relief valves have however been fitted to the turbines.

* THE BEAMA JOURNAL, 63, No 2, pp 46-51

Upper Reservoir

The upper reservoir has been formed by raising the water level of Llyn Stwlan lake from 1 580 feet (482 m) to a top water level of 1,648 feet (500 m) by a 900 feet (274 m) long buttress dam 118 feet (36 m) high. The daily rise and fall of the water level will normally be 65·5 feet (20 m). The dam has gravity sections at the east and west flanks with a gravity spillway on the west flank. Buttresses are spaced at 50 feet (15 m) centres along the 800 feet (244 m) massive buttress section. These have a minimum thickness of 15 feet (4·6 m), while the downstream face of the walls between the buttresses is formed by horizontal ellipses with a minimum thickness of 12 feet (3·7 m). Any overflow will discharge down the spillway to the stream below.

Level relays are installed to ensure that pumping stops when the upper reservoir is full, since the stream cannot carry the full pumping discharge of 3 000 cusec (84 960 litre/sec). The upper reservoir has a natural catchment area of 165 acres (66·8 ha) and the average rainfall is of the order of 120 inches (304 cm) each year. This small catchment will make a contribution of only 4 million kWh to the total annual output.

Pressure Conduit System

Approximately 60 feet (18·3 m) upstream from the dam are two intakes consisting of two 14·5 feet (4·4 m) diameter vertical shafts 680 feet (207 m) deep. The intakes incorporate 14·5 feet (4·4 m) motor-wound Stoney gates designed for gravity closure. Fixed screen and maintenance bulkheads are installed upstream from the gates.

Each of the two vertical concrete-lined shafts bifurcate at the bottom into tunnels, each about 10 feet (3 m) in diameter and about 3 800 feet (1 158 m) long. With this arrangement, one shaft and its two tunnels can be drained for maintenance and inspection while the machines fed by the other two tunnels are operating. Over a distance of approximately 1 800 feet (5·49 m) upstream from the tunnel portal, the tunnels have welded steel linings surrounded by concrete, giving an internal diameter of 9·6 feet (2·8 m); the remaining length of each tunnel—1 950 feet (594 m)—to the bifurcations at the base of the shaft are lined with 18 inches (46 cm) of concrete, giving an internal diameter of 10 feet 8 inches (3·3 m).

The four tunnels emerge about 200 feet (61 m) above the power station level at a portal chamber where dismantling pipes are provided for access to the tunnels and penstocks. The welded-notch ductile steel penstocks are 7 feet 6 inches (2·3 m) in diameter and about 660 feet (201 m) long. Owing to the short length of

pipes, anchor blocks are required only at the top and bottom.

Each pipeline bifurcates behind the power station, the upper branch being connected to the turbine inlet and the lower branch to the pump discharge. All these pipes are surrounded by mass concrete in a thrust block immediately adjacent to the upstream wall of the station.

Lower Reservoir

The lower reservoir has been formed by building a concrete gravity dam across the natural basin of the Afon Ystradau river. This dam is 40 feet (12 m) high and about 1 800 feet (549 m) long, with a normal operational daily rise and fall of water level of about 18 feet (5·5 m). The lower reservoir has a natural catchment area of 2 350 acres (950 ha) and the average rainfall is 90 inches (229 cm) a year.

The spoil from the excavations for dam foundations has been used to conceal a considerable length of the downstream face of the dam.

Power Station

Situated on the west bank of the lower reservoir, the power station contains four 75 MW alternator/motor-turbine-pump vertical sets.

Excavation for the station is about 80 feet (24 m) deep by 80 feet (24 m) wide and 250 feet (76 m) long, while the total height of the station, including the basement area, is approximately 160 feet (49 m). The station has four main floors, these being the pump basement, the pump floor, the turbine floor, and the operating floor. Between each pair of machines is a large pump dismantling pit extending from the operating floor down to the pump basement; this enables the two main station cranes to handle pump components to the lowest levels. The two electric overhead travelling cranes are suitable for precise handling, with cross-traverse and long travel motions capable of positioning loads to within 0·25 inch (6·35 mm). Coupled together, the cranes are capable of handling a gross load of 240 tons (244 000 kg).

Two cranes for each half of the station are also provided for the pump floor level; each of these cranes has two 10 ton (10 160 kg) capacity grabs, giving a maximum pump erection lift of 40 tons (40 640 kg).

Turbines

The English Electric vertical shaft Francis turbines operate at 428 rev/min and are designed to develop 105 000 h p over a head range of 925 to 1 020 feet (282 to 311 m). The spiral casings are of welded plate lobster-back construction with a cast steel stay-ring, and have been constructed in two halves for bolting together on site. The turbine runners are of cast stainless steel (13 per cent chrome) with an outlet diameter of 74 inches (188 cm) with labyrinth seals. They are mounted on forged steel shafts with self-lubricating upper bearings, while the lower bearing at the base of the draught tube is grease-lubricated. The guide vanes are also of cast stainless steel.

The power station of the Ffestiniog pumped storage scheme during the final stages of construction. The nearly completed upper dam can be seen in the top left-hand corner of the picture, which shows the wild, rugged country in which the project is situated

Pumps

The Sulzer vertical two-stage double-inlet pumps are designed for a discharge of 745 cusec (21 m^3/sec) at 1 000 feet (305 m) head. The power required to operate the pump at rated discharge is 93 600 h p at the coupling (110 000 h p motor power). The main pump casings are of steel with welded steel volutes, and the main suction end-covers are of cast steel. There are two first-stage single-entry and one second-stage double-entry impellers which have been cast from 13 per cent chrome steel. Each pump has two shell-type pressure oil-lubricated guide bearings, one housed in the upper suction cover and the other beneath the lower suction cover.

Shaft Bearings and Couplings

One of the two main thrust bearings is situated between the alternator and the main exciter. This carries the weight of the top shaft, the alternator rotor and the turbine runners, and it will be able to withstand the hydraulic thrust on the turbine runner. The second thrust bearing, at the foot of the pump shaft, carries the weight of the pump shaft and the rotating parts of the pump only. Since the pump has a double entry, the hydraulic thrust will be balanced.

The pump is coupled to the main shaft by a toothed gear arrangement, engaged mechanically by oil pressure supplied by a pump in the basement and applied through the hollow pump shaft. Since it was decided that the complication of a clutch capable of engagement at speed was not justified, the pumps will be coupled to, and uncoupled from, the turbines only when the machines are shut down.

The pump coupling consists of an outer cylinder with 138 internal teeth, both at the bottom and at the top. The teeth at the lower end are in constant engagement with the teeth on the pump shaft, and the cylinder is designed to move upwards to engage the top teeth with those on the turbine shaft when pumping is required. The shape of the male and female teeth is identical and the ends of the toothed rings are chamfered to assist engagement. The probability of direct engagement is about 91 per cent. If the coupling does not engage at the first attempt, the pump shaft will be rotated by a clamp on the shaft operated by a servo.

Oil pressure for operating the coupling mechanism will be admitted to the underside of a piston situated at the top of the pump shaft, and oil pressure on the reverse side of this same piston will disengage the coupling after the locking device has been withdrawn. The oil pressure is applied via a tube inside the hollow shaft; for engagement it will pass between the tube and the shaft, and for disengagement it will be applied via the tube.

Motor/Generators

The four motor/generators supplied by the Heavy Plant Division of A E I Ltd are salient-pole synchronous machines, each rated 78·9 MVA, 0·95 power factor, 16 kV, 3-phase, 50 c/s. These machines are also designed for operation as synchronous condensers. The rotor body is made up of steel discs, each about 3·375 inches (86 mm) thick, shrunk on to the shaft, and the poles are dovetailed into the 14 flats machined on the discs.

Each machine is air-cooled, with circulating fans mounted at each end of the rotor, and four pairs of air/water heat-exchangers are provided for each machine for cooling the air. The thrust bearing, situated above the rotor, is of the Michell type with centre-pivoted pads to guard against the possibility of reverse rotation if the motor supply is lost while pumping. In this event the pump discharge valve will be closed quickly, but this operation may not be quick enough to prevent the water at the pump discharge reversing its direction and that of the pump. Whether pumping or generating, all machines rotate in the same direction to enable the turbine to start the pump and bring it up to speed for synchronising.

The main exciter and pilot exciter are mounted above the main machine and are direct driven. Two permanent magnet a c generators are mounted above the exciters, one being used to supply the pendulum motor of the governor and the other to supply the speed-sensitive devices, such as those controlling the operation of the brakes and the connection of the automatic synchronising apparatus.

Electrical Connections

The output of each machine is controlled by a 16 kV, 3 000 A, 1 500 MVA solenoid-operated oil circuit-breaker supplied by the General Electric Co Ltd. Each pair of alternators is then paralleled and connected to one of the two 160 MVA, 16/275 kV Ferranti OFW transformers. The h v side of each of these two transformers is connected to a 275 kV line to the switching station. These lines will later be looped into a new switching station which is under construction to control the nuclear power station now being built at Trawsfynydd.

The 16 kV switchgear is housed in two switching rooms, each of which accommodates a suite of panels for a pair of sets. The panel for one pair of sets consists of two 16 kV circuit-breakers with an interconnecting panel between these units forming the 6 000 A tee-off to the transformers. The connection from the machines to the switch unit consists of three cables per phase, while the connection from the switchgear to the transformers consists of a single copper bar per phase from the centre unit of the switchgear to the low-voltage terminals of the transformer. These busbars are screened by aluminium sheeting and supported on insulators.

The h v star point of the delta-star generator transformer is directly earthed and each transformer is connected to the 275 kV line. No circuit-breakers are used on the 275 kV side at Ffestiniog, but connection of the lines and the emergency interconnection are effected by motor-driven isolators supplied by the Switchgear Division of A E I Ltd. These isolators are for off-load duty only and are not suitable for switching the magnetising current of the transformers.

Standard forms of protection are used covering the machines and generator transformers. The Magnestat automatic voltage regulation equipment, supplied by the Electronic Apparatus Division of A E I Ltd, consists of a magnetic amplifier working in conjunction with the main and pilot exciter, coupled to a motor-driven amplidyne to give a buck-and-boost control. A compounding system between the automatic voltage

regulators is used to ensure the division of wattless load between the machines.

Reyrolle type H distance protection is applied to the 275 kV overhead lines, using a carrier acceleration interstrip. The line traps in this equipment have been supplied by G E C.

A set of synchronising apparatus is provided for each pair of sets. The automatic synchronising system is so arranged that all four sets can be started at once and the first of each pair of machines to reach synchronous speed will claim a synchronising system. When this set has been synchronised, the system will automatically be made available for the other set.

There are two station auxiliary transformers supplied by Ferranti Ltd and rated at 1 MVA, 16 kV/415 V. The high-voltage side is connected into the centre panel of the 16 kV switchgear already mentioned, so that there is one transformer for each of the two pairs of sets. These transformers provide the normal supplies to the main low-voltage distribution boards and also serve as earthing transformers for the main units. Two 1 MVA transformers—one for each of the main distribution boards—are also installed and connected to the Merseyside and North Wales Electricity Board network for standby duty.

In addition, there is an emergency service distribution board supplied by a 200 kVA automatic starting diesel-driven self-regulating alternator. This board also allows interconnection of the two main low-voltage distribution boards in the case of failure of normal and standby supplies to one of these boards.

The main 110 V station battery for essential and emergency services has been supplied by Chloride Batteries Ltd. It consists of 54 Planté cells, type HHPW 16, assembled in lead-lined wood containers, and has a capacity of 960 Ah at the 10-hour rate at 60 deg F. Special features incorporated in the design of this battery result in a lower internal resistance than that of conventional batteries, increasing the efficiency at high rates of discharge and enabling it to perform the same duty as a conventional 1 600 Ah battery. It will be required to supply a continuous load of 5 A for control devices and circuit-breaker closing and tripping. In an emergency, the battery will also supply lighting (40 A for 2 hours) and feed the bearing oil pumps (for five minutes before shutdown).

Power is also supplied to the lower dam for the operation of the discharge regulators, and to the upper dam for the automatic operation of the motor-wound intake gates. These gates are solenoid-tripped and closed under gravity. Separate batteries are installed in the northern valve house at the lower dam and in one of the intake towers of the upper dam for the emergency operation of the discharge regulators and intake gates respectively. Duplicate power and signal cables are provided for the intake gates at the upper dam.

The main plant contractors are: generator/motors—Associated Electrical Industries Ltd; water turbines, pumps, valves and coupling—the English Electric Co Ltd, in association with Sulzer Bros (London) Ltd; generator transformers—Ferranti Ltd; 16 kV switchgear—the General Electric Co Ltd of England; 275 kV isolators—A E I Ltd; automatic control system—the English Electric Co Ltd.

Final Stages of the Cross-Channel Power Link

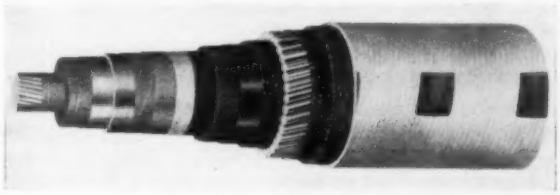
THE next few months should bring about the realisation of an idea first suggested some 40 years ago—that of linking Britain and France electrically. Many years had to pass before equipment became available which was capable of transferring the loads now envisaged, but ten years ago the national electricity undertakings of both countries, after discussions with the British and French cable manufacturers, took the decision to go ahead with the project for a 200 kV 800 A d c circuit with appropriate conversion equipment at each end.

In order to assess the practicability of the cable scheme, the Central Electricity Generating Board agreed that cable-laying trials should be carried out in 1958, and these were conducted jointly by British Insulated Callender's Cables Ltd and Siemens Edison Swan (now part of the A E I Cable and Construction Division) on behalf of the C E G B. An account of these trials was given in our issue of November, 1958.*

The final stages of the project were reached last May, when the motor vessel, *Dame Caroline Haslett*, set out from Dungeness, carrying in her holds two 28 000 yard (25·6 km) lengths of power cable weighing 1 200 tons (1 219 300 kg) in all. Her task was to lay two 15 mile (24 km) lengths of the cable from the coast of Kent to the middle of the English Channel, where they would be jointed by French cable engineers to the French half of the link which had already been laid from mid-Channel to Le Portel, a seaside suburb of Boulogne.

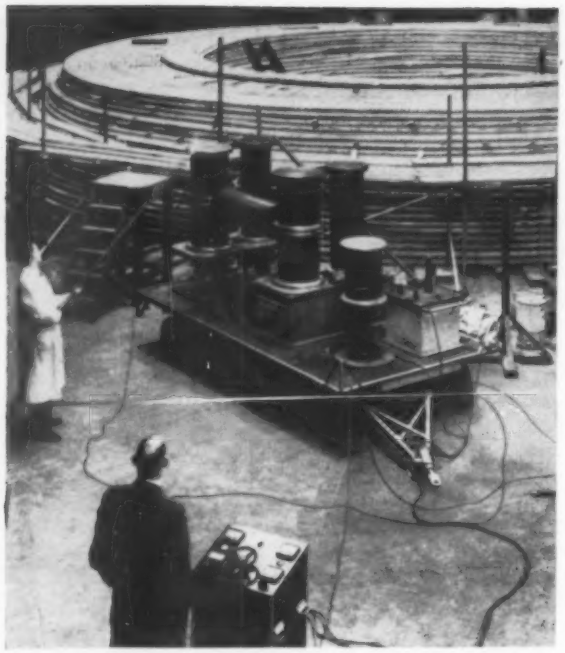
From Dungeness, the sea cable is connected by a 4 mile (6·4 km) underground cable to Lydd, in Kent; from Le Portel the connection is by land cable to Echingen, just to the east of Boulogne.

The total length of the cable link, including the submarine and land sections, will be about 38 miles (61 km) between the converter stations at Lydd and Echingen. At Lydd, connection will be made to the



A section of the 0·525 in² (339 mm²) single-core cable used in the Cross-Channel power link and described on the next page

* THE BEAMA JOURNAL, 65, No. 4, p. 164



This picture shows the d c voltage testing of the finished cable before leaving the manufacturer's works

British grid via a 275 kV line to Canterbury, and from Echingen 225 kV connections will go out to Amiens and Holgue.

The Cable

The cable itself, as developed successfully for the sea trials, is of the impregnated paper-insulated solid type. Each cable operates respectively at 100 kV positive and 100 kV negative to earth.

The submarine cable conductor is of 0·525 in^2 (339 mm^2) cross-section and consists of stranded copper wire lapped with an electrostatic screen. The solid type impregnated paper insulation, also lapped externally with an electrostatic screen, is sheathed with lead alloy 'E' which is protected against corrosion by vulcanised rubber tapes. Armouring is provided by a single layer of 0·232 inch (5·9 mm) galvanised steel wires with appropriate beddings and servings. The cables weigh about 39 lb per yard (19·3 kg per m) in air and about 28 lb per yard (13·9 kg per m) in sea water.

Anti-twist tapes are applied over the lead sheath and under the anti-corrosion protection. These tapes are to ensure that the cable is not damaged under the excessive tensions that may be required to lift the cable out of the sand on the sea bed during recovery after a possible fault. The design stress of these cables is about 150 kV/cm at ambient temperature.

Larger conductor sizes have been used for the land cables, because of the inferior heat-dissipating properties of the soil compared with those of the sea. Over sections of the route where the normal type of loam is found, a conductor size of 0·6 in^2 (387 mm^2) is employed, but in the shingle areas, which have very poor thermal dissipation properties, a conductor of 0·925 in^2 (598 mm^2) is necessary.

The land cable is similar in design to the submarine cable, except that over the Lydd-Dungeness lengths, neither anti-twist tapes nor submarine anti-corrosion protection are used, and the armour wires are considerably smaller in size.

Work on making the cable began several months ago at A E I's Woolwich factory, on the south bank of the Thames, and at British Insulated Callender's (Submarine Cables Ltd) factory at Trafford Park, Manchester. Each company was responsible for producing one 15-mile (24 km) leg of the submarine cable as a continuous length, and one four-mile (6·4 km) leg of the land cable. At all stages, through manufacture to the completion of loading, the cable has been rigorously tested.

The *Dame Caroline Haslett* is an up-river class collier of 2 700 tons, with a length of about 230 feet (70 m) and a beam of 40 feet (12 m). Equipment has been designed and manufactured to adapt her for the laying operation and for subsequently carrying out repairs if found necessary.

For the laying operation the following equipment has been fitted: fairleads to lead the cable from Nos 2 and 3 holds; 'A' frame roller gears along the deck to lead the cable to the brake gear; brake gear on the poop of manual screw type with specially designed shoes to give an even spread of pressure over the cable as it passes through; a hydraulic capsule system to measure cable-laying tension; a system for measuring the yardage of cable which has been paid out; and a stern sheave which is a steel fabrication of about six tons (6 096 kg) in weight, fitted with a special movable self-adjusting central fin which allows the cable to be aligned against prevailing current conditions as it is laid.

Provision for Repair and Recovery

It is not expected that recovery and repair operations will be necessary, but nevertheless it is sound engineering policy to provide for this eventuality and the following equipment has been manufactured: a heavy fabricated bow sheave; a cable repair platform with superstructure; quadrant gears; a heavy twin capstan diesel-powered winch gear over No 1 hold and two transporter gears over No 3 hold. The large twin capstan gear comprises a 90 b h p diesel engine driving a horizontal-piston Williams-Janney pump feeding hydraulic power to two oil motors which are connected to the mechanical systems of the winch gears. The main winch barrels are 8 feet (2·44 m) in diameter and the cable fleeting action is by both rings and knives. Tension in the cables is measured by a torsionmeter shaft system and speeds of hauling are recorded by a d c tacho-generator system. Control of the gear is effected from a console system on the wheelhouse superstructure.

The Cross-Channel power link is an outstanding example of the closest co-operation between the national electricity undertakings in Britain and France and the electrical manufacturers. It is also unique in that it connects for the first time the integrated British electricity supply network with the integrated Continental system, and that it is the highest d c voltage ever transmitted by cable—at least in Europe.

The link is expected to be in operation by the end of this year.

The 13th British Electrical Power Convention

'ELECTRICITY in the Prosperity and Welfare of the Nation' was a theme that gave this year's British Electrical Power Convention the opportunity to review past developments in the production and use of electricity and to discuss their meaning for the future. The Convention heard papers from spokesmen of generating, transmission, distribution, and manufacturing interests in Britain and, for the first time, it heard a paper from a Canadian representative; this gave perspective to the discussion of British conditions and was very well received.

A survey of the main themes discussed in the papers is given below. It reveals an electrical industry very conscious of the increasing importance of electricity to the nation and aware that a critical stage has been reached in electrical development. Possible rates of expansion in the demand for electricity are so large that great care has to be given to the investment decisions related to it.

Mr Stanley F. Steward, Director of The British Electrical and Allied Manufacturers' Association (The BEAMA) outlined very clearly the situation facing the manufacturing industry. In a paper, *British Electrical Manufacture in the National Economy*, he pointed out that, by its very nature as an expanding and technically progressive industry, electrical manufacture makes large demands for capital investment. The success of the industry depends on its ability to continue the present substantial rate of capital investment. Making allowance for ancillary activities (for example, separate research laboratories) it is probable that a total investment of £400 million has been made over the ten years 1950-59; and two-thirds of this took place during the last five years.

The three-fold increase in the annual level of the electrical manufacturing industry's capital investment between 1950 and 1959 is significant. It is a higher rate of increase than other manufacturing industries, and is more than 2½ times greater than the average for all manufacturing in Britain.

Electrical Research

The same reasons that have led the industry to undertake substantial capital investment to maintain its position against world competition have placed great emphasis on research. Between 1955 and 1958 the electrical manufacturing industry's annual expenditure on research almost doubled, rising from £33 million to £65 million. In addition, much valuable work is done in co-operation with research organisations of public bodies such as the Electricity Council, the Central Electricity Generating Board, and the Atomic Energy Authority. When all these activities are taken into account it seems probable that the electrical industry as a whole is spending £80 to £90 million per annum on research.

The full fruits of this investment in research by the manufacturers will be gathered in the future, but already increases in the efficiency and size of generating sets have been made possible through the research and development programmes of the electrical industry There is every prospect that striking progress in the design of conventional generating sets will continue.

Electrical manufacture is the largest industrial employer of both scientists and technicians, and the industry's increasing need of design and research staff is likely to make heavy demands on the available trained personnel. In 1959 the electrical manufacturing industry employed about 21 per cent of the total number of qualified scientists and engineers in the whole of the manufacturing industries.

In such a situation, Mr Steward suggested, a detailed study of the future trends of growth in all the various sectors of the electrical manufacturing industry would be of inestimable value in guiding future planning. He suggested that it could be best undertaken on behalf of the whole industry through a co-operative effort by the manufacturers, adding 'There is an urgent need for such information at the present time and this is a service which The BEAMA must be ready to undertake for its members'.

Power Plant Expansion

In his paper, Mr Steward gave preliminary consideration to the future of two distinct sectors—power plant and domestic appliances. The present plans for increasing the installed capacity of Britain's electricity supply system envisages the commissioning of 2 000 MW to 2 500 MW of new generating plant each year. In England and Wales the C E G B is planning to have available at the end of 1964 a total net output capacity of 34 800 MW.

Acknowledging that the forecasting procedures of the electricity supply industry were thorough and well informed, Mr Steward nevertheless felt that this programme seemed based on the assumption that there would be some decline in the 6.9 per cent average rate of increase which has occurred in recent years. He believed there were grounds for thinking that a programme on this basis left too narrow a margin of capacity under severe weather conditions. Support for this view came towards the end of last year, when for a period of five or six weeks the rise in demand approached 16 per cent and brought the rate of increase for the whole year to 14 per cent.

'It is evident that the power plant programme needs a careful re-appraisal, which would have to take into account the findings of any investigation into the nature of the unexpected upsurge and the extent to which it is likely to be repeated in the future' said Mr Steward.

Some pointers occur in the statistics of sales of domestic appliances and in the growing recognition of the economy and convenience of electricity when properly applied to space heating. 'It may well be found that a new trend is emerging in the continued change to electricity as a source of power' said Mr Steward. 'When regard is paid to the pressure on industry to increase productivity, the growing adoption of automation, the Clean Air

legislation, and the necessity to eliminate domestic labour, it is difficult to resist the view that the rate of growth of demand will be greater in the next decade than in the last.'

The growth of electrical load was discussed by Dr A. E. Grauer, Chairman and President of the British Columbia Electric Company Limited. In a paper, *The Electrical Power Industry in Canada*, he started off by considering load growth in different countries.

Demand for electricity does not seem to increase rapidly in under-developed regions As soon, however, as transportation and processing of raw materials begin to get under way, the 'take-off' stage is encountered. Requirements of power then speed ahead of population growth and the nation's total output of goods and services. At a later or intermediate stage, requirements tend to become more in step with the rate of growth of gross national product Finally, as an economy enters a more mature stage, its rate of electrical growth in *per capita* terms tends to fall back to around 4 or 5 per cent per annum.

Requirements are growing at *per capita* rates in excess of 10 per cent in countries like Venezuela, Israel, Hungary, and the U S S R. More mature economies like the U S A, Switzerland, Belgium, and the United Kingdom are usually to be found in the 4 to 8 per cent range.

Canada's experience in this regard is interesting. They find themselves in a position closer to the more mature nations of the world. Canada, despite her relatively small population of about 18 millions, is one of the world's largest producers and consumers of electric power. In terms of total output she is roughly on a par with the United Kingdom. On a *per capita* basis she is second only to Norway. From such a high base, her current rates of growth appear modest when measured in percentage terms. Allowing somewhat more than 2 per cent per year due to population growth, Canada's current rate of electrical growth is about 7 per cent per year.

Looking over the next 20 years, Dr Grauer concludes that the power requirements for Canada might grow at an average rate of more than 6 per cent per annum and require the construction of upwards of 50 000 MW of new capacity by 1980.

British Capital in Canada

In contrast to oil and natural gas, Canada's electric power resources have for the most part been developed by Canadian capital, and Dr Grauer saw no great difficulty in raising the required funds for future expansion (about $2 000 million by 1980).

There are, however, proposed new hydro developments—notably in the Peace River in British Columbia and Hamilton Falls in Labrador—which are not part of an existing utility system. These will have to be financed from a standing start. However, the size of each of these proposed projects is such that it is questionable whether they could raise all the new money required in Canada over the period of construction. Here, it would appear, is an opportunity for British investment in Canada; and it is an interesting fact that in both these projects, so far, British capital has taken a prominent part.

The growth of load in Canada can thus be seen to be very similar in size to that expected in Britain. Sir John Pickles, Chairman of the South of Scotland Electricity Board and President of the Convention, saw no reason to doubt a doubling of consumption in Britain during the next ten years. In his Presidential Address he drew attention to the fact that our present annual consumption per head is less than one-half that of the present U S A figure and one-third that of Canada. This indicates the very large potential increases that we may experience.

Looking to the prospects in the period 1970-80 Sir John suggested that one could not conceive that the factors at present compelling expansion would be spent. 'I can feel no doubt that the potential expansion will still exist. Moreover, note must be taken of our increasing population which, it is estimated, will have grown by 10 per cent by 1980. Trying hard to keep one's feet on the ground, it does not seem at all impracticable for the 1970 consumption to be doubled again, possibly by 1980 or by 1985 at the latest.' This would imply that British installed capacity would be more than 100 000 MW by 1980-85.

Transmission Expansion

A somewhat similar expansion in load was envisaged by Sir Christopher Hinton, Chairman of the Central Electricity Generating Board. In a paper, *The British Electricity Transmission System*, he recalled that the maximum demand on the Board's system so far was 24 449 MW on December 13, 1960, adding 'The trend of past years shows that this demand may be trebled in fifteen to twenty years' time'. By that time, if the pattern of generation envisaged today is followed, the heaviest concentration of power stations will be in the central coalfields.

The general level of bulk power movement envisaged is in the region of 4 000 MW over distances of 50 to 100 miles (80 to 160 km); but transfers as high as 8 000 MW from the central coalfields towards the South Midlands, and a throughput of 6 000 MW to the London area—a total distance of 100 to 140 miles (160 to 225 km)—are likely to be required. With this arrangement the movement of coal over long distances by rail will have virtually ceased, and sea-borne supplies reduced to roughly half of their present value.

Sir Christopher explained that considerable thought had been given to the best means of dealing with demands of the order of 70 000 MW. Several questions arise. Can a single national grid be continued and enlarged to carry this load, or will it be necessary to break it down into areas with more localised siting of generating plant? Would the problem best be met by breaking down into area grids, heavily interconnected by asynchronous links ?

Careful study of the complicated problem led to a decision to develop a 420 kV national system with a nominal voltage 5 per cent less than this; at this voltage the existing 275 kV heavy-duty lines can be converted for use. If a higher voltage such as 500 kV had been adopted, the considerable increase in capacity of the 275 kV lines by up-rating to the new voltage would not have been achieved, he explained, because their design

places a limit of 400 kV on them. In these circumstances there would remain an extensive 275 kV grid with a 500 kV network superimposed on it.

In adopting 400 kV as its new transmission voltage, the Generating Board is making the assumption that a voltage of 700 kV will be practicable by the mid-1970's, and research to ensure this is being put in hand. As the load grows beyond 70 000 MW in the years after 1975, it is possible that a 700 kV large-mesh network could be superimposed on the 400/132 kV system. The fact that this 700/400/132 kV system gives a better pattern than a 700/500/275/132 kV system was another factor leading to the choice of 400 kV as the new transmission voltage.

New Loads

Some of the more recent developments contributing to the increase in power demand were discussed by Mr R. R. B. Brown, Chairman of the Southern Electricity Board, in a paper *Some Aspects of Efficiency and Economy in Distribution*. Floor-warming by buried cables has found wide application in new houses, shops, offices and stores. Current research and development effort is being directed towards the improvement of installation techniques and practice. One example of this work is the research into new methods and materials to achieve a simpler and speedier means of laying the concrete screed without risk of subsequent cracking.

Newer applications of floor warming include the pre-drying on a warm floor of green bricks before firing (a method that reduces the drying time from 3½ to 2 days), the laying of cables below the floor insulation of cold stores (to prevent freezing of moisture in the subsoil), and the floor warming of buildings used for the production of concrete bricks and blocks (to enable production to go on all the year round). Heating cables are also being developed for amateur greenhouses to provide frost protection by off-peak heating; this may in turn lead to the use of thermal storage heating in commercial greenhouses.

Another application of off-peak floor warming is for the maintenance of correct temperatures in poultry brooders, where it has the advantage of giving a reserve of heat without fire risk. A warmed floor area of about 6 feet by 7 feet (1·8 by 2·1 m) loaded at 2 kW is quite adequate for 1 000 birds, and installations are generally in almost continuous use throughout the year. This development has a big potential in the large-scale production of broilers; the broiler industry produced 100 million birds in 1959 and expects to produce 400 million in 1965.

Further use of buried cables to reduce accidents and delays caused by snow and ice on roads can be expected. The first schemes at Slough, Edinburgh and Kingston took a few hundred kilowatts only; but a recent proposal to use road heating on the Chiswick fly-over and approach roads would require 8 500 kW. Research is being carried out into the possibility of using a conducting road surface material heated by the application of a low voltage from buried electrodes in order to simplify road repairs.

Electricity for process heating is making rapid headway in most industries because it offers extreme ease and accuracy of control, improvement in working environment and increased output per man. Induction heating and dielectric heating are contributing to the development of automation by the simplicity with which these heating methods can be fitted into a production line as an integral part of the process.

The more familiar resistance heating continues to find new applications in industry. An outstanding example is in pottery manufacture, where the intermittent electric kiln—generally regarded a few years ago as uneconomic—is widely used for regular commercial production. More than half of all decorated ware is now fired by electricity.

More electricity is also being used for steel making. In 1960 the U K production of steel in electric furnaces amounted to 1 685 500 tons and is expected to rise to 4 000 000 tons in 1965. Electric furnaces now being developed include some with a capacity of 110 ingot tons and a rating of 40 000 kVA.

In agriculture, electric crop drying is making increasing headway. Other applications are being found for electricity in controlled irrigation, hydro-cooling, and the artificial lighting of plants at night to promote photosynthesis.

Domestic Equipment

As far as domestic equipment was concerned, Mr Steward saw all evidence leading to the conclusion that there will be a steady growth in demand throughout the next decade. 'First,' he noted, 'there is the progressive policy of the Supply Industry which has already resulted in the addition of about 4½ million consumers since Vesting Day. Then there is the significant social trend of the increasing employment of married women, amounting to a total of about 4 million at the present time. This has opened up the market, not only through increased purchasing power, but also by accentuating the need for labour-saving and automatic electric appliances in the home. Another factor is the spread of demand for household amenities, previously confined largely to the upper and middle income groups, to the wider working population. Finally, the magnitude of the potential demand is shown by the present market penetration in the U K compared with the U S A.'

Mr Steward calculates that the overall picture is such that the domestic electric appliance industry will have a total output of £240 million by 1965 and approaching £340 million by 1970. The import-export position will have an important bearing on this. In 1959 imports were £11 million; in 1960 they were £12 million. The leading supplier has been Western Germany, other major suppliers being Sweden, Italy, the Netherlands, and the U S A. On the other hand, Western Germany has been our best export market for domestic washing machines and one of our good markets for domestic appliances generally 'Reciprocal trade between countries with high living standards seems likely to be an important factor in the future pattern of the domestic appliance business,' said Mr Steward.

Exports

Selling abroad in the highly competitive world markets of today is a difficult and onerous business Success in

exports is, therefore, one of the acid tests of the efficiency of an industry, as well as of a company. In this respect, Mr Steward emphasised that the electrical manufacturing industry as a whole can stand comparison with any other. In the early post-war period the industry emerged as a leading exporter, a position which it has maintained ever since. Last years' total of electrical and allied engineering exports reached £293.4 million—about 3½ per cent more than the previous year and a new record for the industry. But there is no complacency, and electrical manufacturers are conscious that a much greater increase will be necessary if they are to hold their own in the world scene.

The leading markets in 1960 and the amount exported to them were as follows: Australia, £27·3 million; South Africa, £22·4 million; Canada, £19·5 million; India, £16·5 million; U S A, £13·7 million; New Zealand, £12·5 million. The importance of the Commonwealth is clear from these figures, the five major Commonwealth countries accounting for over one-third of the industry's total sales overseas. Large markets have also been developed in other parts of the Commonwealth, notably West Africa—where sales to Ghana and Nigeria totalled £11 million; and Rhodesia and Nyasaland—where exports reached nearly £9 million.

A rapid trade expansion is developing between the industrialised countries of Western Europe, and the electrical industry is paying increasing attention to this market. Exports with a value of £70 million were made to Europe last year—£34 million to Common Market countries (an increase of 25 per cent) and £21 million to E F T A countries (an increase of 16 per cent).

The B E A M A's Golden Jubilee

Mr Steward's paper looked back over half a century of development to the time when electrical manufacture was a new industry playing only a small part in the national life. Since this is the Golden Jubilee year of the British Electrical and Allied Manufacturers' Association, he linked the trade association with the growth and development of the industry, giving an account of the history of The BEAMA and of the benefits of co-operation in the industry during the last fifty years.

Over this period the range of electrical goods produced in Britain has increased substantially and the industry now supplies about £1 600 million of electrical and allied engineering products a year. Nearly one-fifth of this output is exported, representing about 10 per cent of all the U K exports of manufactured goods, and one of the most important sections of the national export trade. Total employment in the industry is close on 800 000, representing a total family population of nearly two million, so that a significant proportion of the country's citizens depend on electrical manufacture for their livelihood and welfare.

A characteristic feature of the industry has been its remarkable growth: its volume of output during the post-war period has increased faster than any other major industry. Taking the Board of Trade index of production for 1948 as 100, then the 1960 figure for electrical manufacturing is 229; for vehicles 226; for chemicals 213; and for all manufacturing 159. Over the same period, when electrical production has more than doubled, employment in the industry increased by about 40 per cent, indicating a strong rising trend in productivity—a factor of vital importance.

Two sectors of the industry have shown outstanding growth over the last decade. These are domestic electrical appliances and the electronics and telecommunications groups of equipment. Output here quadrupled between 1948 and 1958, appliances now representing 10 per cent of the total output of the industry, and electronics and telecommunications equipment, 30 per cent.

The Trade Association's Work for the Industry

The key position held by electrical manufacturing in the national economy is closely linked to the effectiveness of The BEAMA as an instrument for co-operative action. As the industry's main trade association, it plays an important part in assisting the electrical industry to use its resources to the best advantage.

Mr Steward maintains that the key to adaptation to meet the rapid pace of technological advance and changing trading conditions throughout the markets of the world is information in its widest sense. In considering the future role for the industry's trade association, he holds that it is in the field of information that The BEAMA can render an important service. 'The whole field of the collection and dissemination of statistics and information should form a major part of the work of a modern trade association' he stated. 'The BEAMA Survey of the European Common Market, the first of its kind to be undertaken by a trade association, has proved its worth and attracted much favourable comment in the electrical industry and other quarters.'

There are a number of other services which have been provided by The BEAMA over the years and which have been a source of strength to the electrical industry. Throughout the greater part of the last fifty years the association has provided a lead to the engineering industry in the matter of contract conditions and its work in this field has achieved an international importance. The BEAMA has always regarded up-to-date Standards as a matter of great importance to the electrical manufacturing industry, with its continuous and rapid developments, and today there are nearly 2 000 BEAMA representatives on over 600 B S I technical committees, sub-committees and panels. The BEAMA representatives play an influential part, through the B S I, in the settlement of international standards. The electrical industry has always been in the lead in technical education, and here again The BEAMA through its Education Committee has played its full part. The original BEAMA scholarships, founded in co-operation with member-firms, gave a much-needed stimulus to the training of electrical engineers and designers in Britain.

In the electrical industry these matters are of special importance because of the key position of electrical manufacturing in the economy. Electrical manufacturing is of vital importance today and seems bound to be the key industry of the future. It has drawn strength in the past from enlightened and constructive co-operation in all its sectors and The BEAMA has a great opportunity and responsibility for helping the industry to remain strong and progressive in the exciting period which lies ahead.

Notes

Distillation Plant for Kuwait

G. & J. Weir Ltd, the Glasgow engineers, are to install another of their 'Multiflash' sea water distillation plants at Kuwait, on the Persian Gulf.

This installation for the Kuwait Oil Co Ltd will be at Mina-el-Ahmadi, and will consist of a single 21-stage plant measuring 58 feet (17·7 m) long, 19·5 feet (6 m) wide, and 18 feet (5·5 m) high, with an output of 600 000 gallons (2 728 000 l) of fresh water a day.

The order follows the highly successful commissioning of two similar installations last year—one of which was the world's largest 'flash' type plant—for the Government of Kuwait, producing 2 million gallons (9 000 000 l) daily.

Erection of the new installation is to be completed in November this year—only 43 weeks from the date of order, and with its commissioning a month later, Kuwait will be using nearly 4 million gallons (18 000 000 l) of fresh water a day from plant of Weir manufacture, and the world total output of 'Weirwater' will reach well over 11 million gallons (50 000 000 l).

Largest Generator Going to U S A

C. A. Parsons & Co Ltd of Newcastle upon Tyne are to supply the Central Electricity Generating Board with four 500 MW single-line turbogenerators.

These four machines alone are equivalent to an increase of more than six per cent in the total capacity of generating plant at present installed in the U K. The value of the order, which will include the associated feed-heating plant and turbo-driven boiler feed pumps, will be about £13 million.

This new order will make a total of six machines of 500 MW capacity (and over) to be constructed by Parsons for service in this country and overseas. One of these, a 550 MW machine was the first of such a size to be ordered in Great Britain and is to be installed in the Thorpe Marsh generating station near Doncaster in Yorkshire. It will be commissioned early in 1963.

Another 500 MW machine of particular interest is at present under construction at Parsons' Heaton Works for the Tennessee Valley Authority for installation in the Colbert Steam Plant, U S A. This machine will be the largest ever to be exported from any country.

Contracts from Australia

Two contracts, worth together approximately £150 000, have been received by A. Reyrolle & Co Ltd, of Hebburn, from the Hydro-Electric Commission, Tasmania, for the Poatina Hydro-Electric Power Station. These contracts were secured in the face of strong competition.

The first is for eight 220 kV 5 000 MVA air-blast circuit-breakers, current transformers and ancillary equipment. The other is for thirteen 110 kV 3 500 MVA small oil volume circuit-breakers with current transformers and ancillary equipment.

Largest Transformers Ordered by C E G B

Ferranti Ltd have received an order from the Central Electricity Generating Board through the Northern Project Group for transformers of the highest rating yet ordered by the Board.

The contract is for two 400 MVA 3-phase 50 c/s double-wound transformers for installation at Blyth 'B' Power Station in Northumberland, to step up the generator voltage to 300 kV and to provide a direct connection to the super-grid. The transformers will be water cooled and will be fitted with Ferranti high-speed resistor-transition on-load tap-changing equipment.

The order follows that for the 310 MVA transformers awarded to Ferranti Ltd by the C E G B in 1959 and which at the time were the largest transformers ever ordered from a manufacturer in this country by a British customer. It brings the total number of Ferranti transformers supplied or under construction for Blyth Power Station to 8 units of a total capacity of 2 000 MVA.

Electronic Control Increases Output

An electronically-controlled drilling machine equipped with a multi-spindle head, which now enables a girl operator at the Coventry Telephone Works of the General Electric Co Ltd of England to quadruple her output, has paid for itself by the saving of tooling costs on its first job. For future jobs, the only extras will be the negligible cost of new tapes, and in all cases design modifications can be made much more cheaply than when using conventional drilling methods. Altering a jig can take up to ten hours, but a new tape can be made in fifteen minutes.

The G E C's problem was to make varying numbers of holes in small batches of printed circuit boards of several different designs. An E M I-Grimston positioning table, supplied by E M I Electronics Ltd, was equipped with a seven-spindle drilling machine designed and constructed by G E C's Works Technical Services Department. The drill is also controlled by the E M I system.

The positioning equipment uses a measuring element with an electrical accuracy of ±0·000 5 inch (0·0127 mm), which gives a guaranteed positional accuracy of the table of ±0·002 inch (0·0508 mm) with repeatability to ±0·001 inch (0·0254 mm). Information can be fed into the system by punched tape or set up on dials.

It is reported that the girl operators prefer using the E M I system, as it imposes less physical and mental strain than conventional drilling methods; the latter always carry the risk that a girl may accidentally overlook drilling one or more holes. Such an oversight would not be noticed until the printed circuit boards reached the inspection department, when considerable delay would be caused while the boards were returned to the machine room for further holes to be drilled.

A New Mechanical Research Laboratory

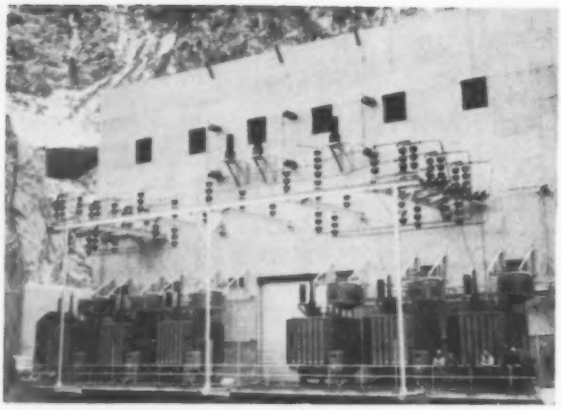
The well-known firm of C. A. Parsons & Co Ltd, of Newcastle upon Tyne, have been responsible for the design and construction of some of the largest turbo-generators in the world.

One of the chief factors which have contributed to the high standard of reliability and efficiency of the company's products is the emphasis which for more than half a century has been placed on research and development.

Just over two years ago, the laboratories at the Nuclear Research Centre at the company's Heaton Works were commissioned, and now comes news of the construction and equipping of a new Mechanical Research Laboratory, designed to ensure that the company's interests in the rapidly changing requirements of the power industry are fully supported by the most up-to-date experimental facilities.

A feature of the opening ceremony was

The cordless automatic private branch telephone exchange which has been developed by Standard Telephones and Cables Ltd in co-operation with the British Post Office. The board is provided with lamps, keys and push buttons for the use of an operator with normal sight, whereas special plungers are fitted into the switchboard to give a blind operator 'fingertip' indications of the state and progress of all calls. It is hoped that this new type of switchboard, in addition to being suitable for sighted operators, will assist in providing employment for blind people in both commerce and industry



The six Crompton Parkinson transformers installed at the Fremont Canyon power station. Single-phase transformers were used, as each one had to be brought singly through the access tunnel, the mouth of which can be seen on the left of this picture

the starting up of 'Bess'—a very modern experimental steam turbine designed particularly to investigate the performance of low-pressure blading. Like all the other test turbines at Parsons, 'Bess' was named after a member of the family of Sir Charles Parsons.

British Transformers for U S A

Crompton Parkinson Ltd have supplied six power transformers valued at more than $200 000 for the Fremont Canyon Power Project in Wyoming, U S A.

An engineering achievement stands today near the spot where a boat of Lieut John C. Fremont, a daring explorer, broke on the rocks in 1842. The canyon bearing his name now identifies a power plant, the completion of which was recently celebrated.

Pathfinder Dam, at the canyon's head, was completed in 1909 as part of the North Platte irrigation project. Authorisation of the Glendo Unit of the Missouri River Basin Project meant that the 300 feet (91 m) head of water from Pathfinder to the Fremont Canyon site could be used to generate power.

To establish the site, a 1 700 feet (518 m) access tunnel was excavated, and an access road and a bridge over the canyon were built. Loose rock was scaled away, and a flat area was blasted out of the sheer rock wall to the water level.

A concrete-lined pressure tunnel connects the reservoir and power plant, 3 miles (4·8 km) apart. The surge tank prominently visible above the power plant is 40 feet (12 m) in diameter and 260 feet (79 m) high, including 156 feet (48 m) below the ground.

Each year the power plant will produce about 235 million kWh of energy. Power flows into an inter-connected Federal network of sixteen plants serving consumers in Wyoming, Colorado and Nebraska.

There are two generators, each of 24 MW; the transformers are multiple-fan-cooled and each is rated at 9 687 kVA single-phase, ratio 115/11·2 kV. The specification provided for nitrogen seals with conservator tanks and off-load tapping switches. Single-phase transformers were used in 3-phase banks, as these could pass through the access tunnel singly.

The transformers were made at the British Electric Transformer works of Crompton Parkinson Ltd at Hayes, Middlesex.

British Equipment Ordered by Finland for U S S R

British Insulated Callender's Cables Ltd announce that the Engineering Division of the Telegraph Construction & Maintenance Co Ltd (Telcon), a member of the B I C C Group, has received a contract from Wartsila-Koncernen A/B, Sandvikens Skeppsdocka, Helsinki, Finland, for all the cable handling equipment for two new cableships they are building for the U S S R. This order is stated to be the largest ever placed for this type of equipment and was secured in the face of keen competition.

The vessels are of 7 000 tons (7 122 tonne) displacement and capable of laying and repairing submarine cable systems including all types of submerged repeaters. The equipment of each vessel, incorporating the latest improvements in submarine cable laying practice, will include two forward picking-up and paying-out gears, draw-off and holding-back gears, dynamometers, bow gear and after laying gear, and all ancillary equipment. The first vessel is required by 1962 and the other is to follow in 1963.

The Telcon firm has had a long and specialised experience in cableships' gear and equipment, beginning with the fitting-out of the s s *Great Eastern* for the first successful Atlantic cable-laying expedition of 1866. The cable-laying gear of the *Great Eastern* was designed and made at Greenwich, and to-day many of the vessels owned by the cable-operating companies and administrations throughout the world are equipped with gear designed and produced at Greenwich.

English Electric Turbines for Canada's First Extra High Voltage System

A contract for two 84 000 h p hydraulic turbines has been awarded to the English Electric Division of John Inglis Co Ltd of Toronto by The Hydro Electric Power Commission of Ontario.

Design work and model testing will be done in the U K by English Electric's hydro-electric division at Netherton and Rugby. Work will start immediately on the fixed blade propeller-type units, with manufacturing operations scheduled to begin late this summer. The turbines will be designed to operate at a head of 90 feet (27 m) at 94·7 rev/min.

When completed towards the end of 1962, the big turbines will be installed at Ontario Hydro's Little Long Rapids generating station on the Mattagami River, some 500 miles (805 km) north of Toronto, Ontario.

The turbines will be similar in design to the sixteen manufactured by the English Electric Group and now in successful operation at Ontario Hydro's Robert H. Saunders generating station on the St. Lawrence River. The power produced at Little Long Rapids will eventually be fed into North America's first extra-high-voltage transmission system serving both North Eastern and Southern Ontario at 460 kV.

Power Plant for Rhodesian Sugar Factory

The Hulett Group of Companies of South Africa have placed an order with W. H. Allen Sons & Co Ltd, of Bedford, for a condensing turboalternator which will provide power for one of their sugar factories on the Triangle Sugar Estate, Rhodesia.

With a power output of 3 000 kW, the plant will comprise an Allen steam turbine running at 6 000 rev/min driving through Allen-Stoeckicht epicyclic speed-reduction gearing a Mather & Platt totally-enclosed water-cooled alternator at 1 500 rev/min.

The turbine is designed to operate with steam at a pressure of 435 lb/in^2 (30·6 kg/cm^2) and 606 deg F (319 deg C), exhausting to a separate basement condenser with a vacuum of 27·5 inch (700 mm) of mercury. The turboalternator will run in parallel with other generating plant at site, the power supply being 6·6 kV, 3-phase, 50 c/s at 0·8 power factor.

Calder Hall Trains Japanese Engineers

Five Japanese engineers who will hold the senior posts in the British-designed nuclear power station now under construction at Tokai Mura, near Tokyo, are being given an intensive training course at Calder Hall Nuclear Power Station.

The Tokai power station, which is being built by the General Electric Co Ltd of England in conjunction with the First Atomic Power Industrial Group—a consortium led by the Fuji Electric Manufacturing Company, will have a net sent-out capacity of 158 MW.

The period of Training at Calder Hall is devised especially to suit the experience and future functions of each man at Tokai. In this way, reactor operators are able to gain experience on the world's first full-scale power reactors under direct supervision of the staff of the U K Atomic Energy Authority. The training course includes a period at the Calder Operation School.

On the same course with the Japanese engineers are two technical trainees from Portugal, one from Germany, one from Finland and one from Argentina, as well as eleven sponsored by the Central Electricity Generating Board and two by the G E C.

Since it started in January, 1957, the Calder Operation School has now trained 532 students from 29 countries.

The New B I C C Research Laboratory

OFFICIALLY opened by H R H The Duke of Edinburgh in May, the new McFadzean Laboratory (named after Sir William McFadzean, the Chairman of British Insulated Callender's Cables Ltd) is the latest addition to the Group's research facilities.

The modern 6-storey building, with 64 000 square feet (5 946 m^2) of floor space, is situated at Wood Lane, some 6 miles (15·5 km) to the west of Central London, on a site which has an interesting historical background. Until the middle of the nineteenth century it was farming land, and Wood Lane itself (now a busy highway) was little more than a cart track.

With the increase in the use of electricity, the various power companies then serving London were looking for suitable spots to erect new power stations. Two of these enterprises—the Kensington and Knightsbridge Electric Lighting Co Ltd and the Notting Hill Electric Co Ltd—combined to form the Kensington and Notting Hill Electric Lighting Company in September 1899 and purchased the Wood Lane site. Work on the erection of a power station began very soon after, and plant and buildings were built and tested in ten months from commencement. Power was first sent through to Kensington in October 1900.

The Origin of the 'White City'

Some eight years later, a striking project began to take shape on a large area immediately to the north of the power station site, and there came into being in 1908 the Franco-British Exhibition, housed in a vast series of white-painted buildings and pavilions of ornate design which immediately became known as the 'White City'—a name which is perpetuated to this day. On part of the old exhibition site there has recently arisen the B B C Television Centre—the heart of the B B C's television service which now covers the U K.

In 1928 the power station was closed down and remained inactive for three years until the site was leased by Callender's Cable and Construction Company in 1931 to provide for the expansion of its research section, then located in Central London and known as the Outside Testing Department.

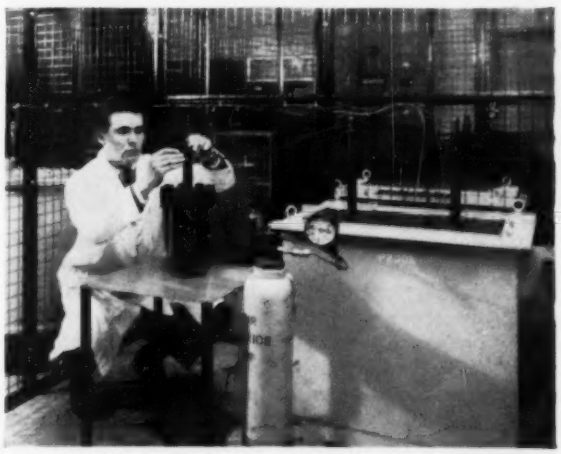
Several alterations were made to the power station site, and by 1934, when the conversion had been effected, the Research and Outside Testing Organisation of Callender's Cable and Construction Company was fully operational.

When C C C C amalgamated with the British Insulated Company in 1945 the Wood Lane laboratories continued as the research centre of the new combine—B I C C. From that time and until the erection of the new McFadzean Laboratory, the plant and accommodation on the site were continually augmented to provide for the research demands of an ever-expanding group. Research Organisation personnel now number about 350.

Several buildings dating back to the original power station and still in good structural condition have been retained because they are well suited to a number of research uses. A familiar landmark which has now disappeared was the power station chimney, 210 feet (64 m) high, erected in 1899. This was employed for many years for testing vertically installed cables and was in fact being used for experiments on the installation of the 330 kV Kariba oil-filled cables right up to the day in 1958 when the ladders required for its demolition were being fixed. A small plaque on the site of its base, in the garden in front of the McFadzean Laboratory, commemorates the part which it played during nearly sixty years of electrical engineering progress.

The new laboratory will take care of something like one-third of the total research work of the B I C C Group. The overall scientific and engineering effort can be regarded as falling into two main groupings—engineering and research. The engineering group has laboratories located in every production unit and their primary responsibilities are to exercise quality control in its broadest sense; to improve existing products, whether it be in the materials or the plant and processes which are used; to develop new products to the stage of final production, and to maintain the necessary technical contacts with customers and others.

The Research Organisation is responsible for carrying out such long-range experimental work as is necessary to feed to the engineering laboratories the information which they need to fulfil their shorter-range objectives, and to conduct basic research in fields of lasting interest, regardless of immediate applicability. In addition, the Research Organisation provides central facilities where they are required by several factories but which demand such specialised personnel or equipment that a number of separate laboratories would be uneconomic or inefficient. The Organisation has ten experimental departments, each working in a well-defined field of

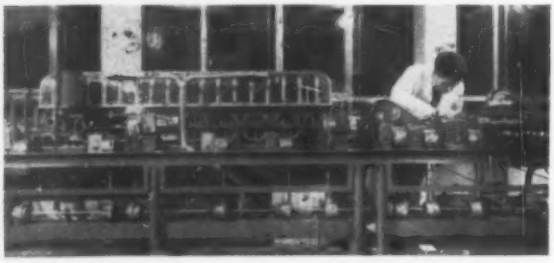


Arranging a test in a high-voltage bay in the Physics Department

science or technology, and four of these are housed in the new building; the others are in other buildings on the site.

The McFadzean Laboratory accommodates the Instrumentation and Control Department, the Physics Department, British Dielectric Research Ltd (a Group subsidiary for research on capacitors), the Diffraction and Microscopy Department, and in addition the Electronic Computer which is an important part of the facilities of the Mathematics Department, the main offices of which are elsewhere. The Laboratory also contains a Drawing Office and the Photographic Section.

The following is a brief outline of some of the work carried on in the various departments; and the particular researches mentioned are but typical of the many others which are constantly in progress.



The miniature Fourdrinier paper-making machine used in the Physics Department on which samples of the special papers required for cable insulation are manufactured

Instrumentation and Control Department

This is one of the departments which provide a centralised service to the Group and is responsible for: (a) developing novel measuring devices, mainly for use in the factories in non-destructive quality control testing; (b) designing and constructing complete schemes of instrumentation, using either specially developed or conventional equipment; and (c) devising automatic production equipment to replace and improve upon existing manual control methods, to improve product quality or to economise in material usage.

The following examples typify the three main fields of work.

The a c spark testing of rubber and plastic cable insulation has been standard practice for many years. The use of a d c spark of very low energy has advantages, particularly that it is non-destructive and non-lethal, and a typical tester, incorporating a novel paper-tape recording device, has been developed for this purpose.

In spiral elements, such as are used for example in electric blankets, the uniformity of the spiral pitch is important to avoid local over-heating. A monitor has been designed and is in use in the factory.

A coach belonging to the Eastern Region of British Railways is in the siding adjacent to the laboratories and is being equipped with instrumentation for surveying the behaviour of overhead electrification equipment. Some of the instruments, which are similar to those provided for the London Midland Region test coach which is already in service, are under test in the laboratory.

The continuous vulcanisation process used in the production of rubber cables requires large and expensive plant which is unsuitable for research or development work. A flash vulcanising unit now enables the fast vulcanising process to be studied in the laboratory with ease, speed and economy.

Many new devices are now available to facilitate the transport of wire through various cablemaking processes and to control quality.

Accurate control of thickness and concentricity of the lead pipe which will be used for the Magna flexible submarine pipeline to convey natural gas from the mainland of British Columbia to Vancouver Island* is a vital necessity. A continuously-operating gauge is now in its final development stages.

The Physics Department

Nearly all the work here is of a long-range nature and largely concerned with the dielectrics used for power cables of all descriptions. The most important topic, and one in which studies have been in progress for very many years, is research into the properties of dielectrics for very high voltage cables and the department is very well equipped for this purpose. With oil-impregnated paper dielectrics, for example, studies begin with the manufacture in the laboratory of the paper itself, which can then be tested in a range of instruments, some specially designed for the purpose, before being built up into cable models in which it is possible to reproduce all the conditions to which a full-size cable will be exposed during its manufacture and service life. Of necessity, the department has its own high voltage testing equipment which is normally of adequate range but, if higher voltages or currents are needed, the larger facilities of the main High Voltage Department† are available.

There is a growing field of work in the possible use of plastics for high voltage cables, but the advances which might still be made in the apparently less glamorous fields of low voltage insulation (rubbers, plastics and minerals, etc) are not by any means overlooked and research programmes are in progress.

Oil-impregnated paper is the only dielectric material which can yet be used for high voltage a c cables, the electrical properties of which are dependent on the properties and quality of the paper. A miniature Fourdrinier paper-making machine is used in the study of the effects of different pulps, pulp treatment processes and paper-making variables.

Numerous methods are used for assessing the quality of laboratory-made or commercial paper, including the use of a surface measuring gauge for recording the surface uniformity of paper.

The use of laboratory models of paper and plastic film cables, on which all electrical properties may be assessed, enables the effect of variables to be studied and reduces the need to manufacture experimental full-size cables. High voltage equipment is used for testing the models, both in impulse and alternating current breakdown strength experiments.

The ability of the dielectric of a cable to withstand mechanical handling is dependent on numerous constructional features. Laboratory models are used to study the influence of design variations and cable manufacturing procedures.

*THE BEAMA JOURNAL, **68**, No. 1 pp 7, 8
†THE BEAMA JOURNAL, **66**, No. 2 pp 67, 68

British Dielectric Research Limited

This serves both the Capacitor Division of B I C C and the Telegraph Condenser Co Ltd, a B I C C subsidiary. The department has sections dealing with all types of capacitors—oil-impregnated paper, electrolytic, metallised plastic, ceramic, etc, and possesses equipment for manufacturing laboratory specimens of all kinds. It also has an extensive range of measuring facilities for the study of initial characteristics and life performance. The work of the department appears at first sight to have certain similarities to that of the Physics Department, with which it collaborates as necessary, but there are actually essential differences between the requirements of capacitor dielectrics and cable dielectrics which account for differences in experimental techniques and methods of attack. A few examples of the work of B D R are the following:

If gaseous cavities are present in a capacitor, the ionic discharges which may occur under electric stress can impair the efficiency of the capacitor and shorten its working life. Techniques have been devised for the measurement of ionisation in a paper capacitor and the influence of pressure upon it, together with methods by which capacitor elements are subjected to the unusual duty cycle imposed upon them when they are used in energy storage capacitors in thermo-nuclear research.

The self-healing characteristic of vacuum-metallised plastic film permits the use of very thin dielectrics and hence permits the size of capacitors to be reduced. This characteristic is investigated both on individual films and in wound capacitors.

Diffraction and Microscopy

This department is concerned mainly with the fine structure of materials and provides an analytical service of this nature to all other departments of the organisation. It has its own research programmes, but these are mainly concerned with improvements in its own techniques. Three main items of equipment are in use.

The X-ray micro-analyser is an instrument of recent development. The specimen which is being examined is scanned by an electron beam only 0·001 mm in diameter. The X-rays which are generated, the wavelengths of which are characteristic of the elements in the surface of the specimen, are analysed and the results displayed either visually on the screen of an oscillograph as an 'X-ray image', or automatically recorded. This enables elements which are present only in minute quantity to be located and identified. The technique is especially valuable in metallurgical studies for the examination of segregates, alloying constituents, etc.

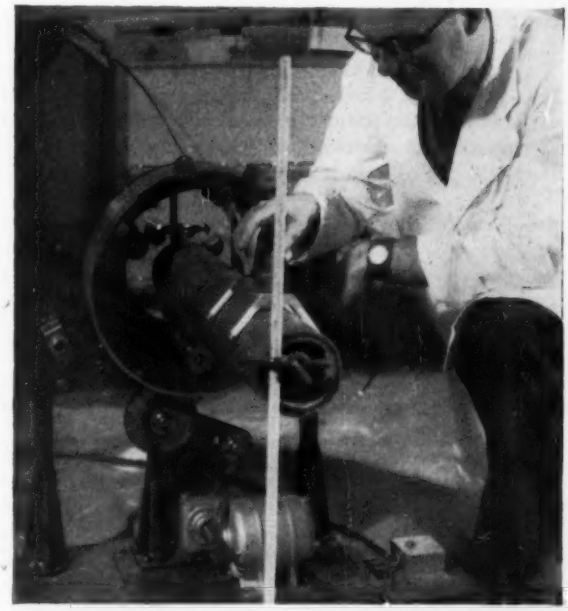
The X-ray diffraction camera is used in the identification of crystalline elements or compounds and for the determination of crystal orientation and texture. The techniques are all well established but the instrument remains one of the most versatile of laboratory tools.

The electron microscope has such resolution that it permits much higher magnifications than are possible with the optical microscope, and it has in addition such depth of focus that stereo-techniques are readily applicable so that photographs may be produced in three-dimensional form.

The Photographic Section

This has many duties of a routine nature but it is also an essential part of the scientific facilities of the laboratories. Its extensive equipment includes high-speed cinematography, and photographic methods are frequently used for measurement purposes. An outstanding example is in connection with the researches being carried out in the organisation's Traction Research Laboratory at Tolworth, near London. In this unique laboratory, the behaviour of the overhead equipment used in electric railway traction is being studied by means of dynamically-similar scale models, and practically all the measurements are being made by cinematographic or special still photographic methods.

The electronic computer, which is in a separate laboratory, is used for mathematical and engineering design problems. The computer is particularly useful for the latter, because it has a much larger store than is usually needed for strictly mathematical purposes. One application is the calculation of the control requirements for installing heavy submarine power cables in deep water. The computer was first used for this purpose in 1956, when the Group installed 93½ miles (150 km) of 138 kV gas-filled cables linking Vancouver Island with the mainland of British Columbia, and an example which is now topical is the calculation of the control charts which were used in the laying of the British section of the Cross-Channel d c power cables for the England-France interconnection.*



The measuring head of the continuous lead sheath gauge in the Instrumentation and Control Department

The McFadzean Laboratory may rightly be described as convincing evidence of the high priority given by B I C C to research to ensure the progressive development of its vast range of products in the service of the electrical engineering industry at home and overseas.

*See p 89 in this issue.

A Computer-Controlled Steel Billet Cut-Up Line

THE first digital computer for the on-line control of an industrial process in the U K is now in operation at a steel rolling mill of Samuel Fox & Co Ltd.

This achievement is the result of a long period of collaboration between the engineers of the steel manufacturers and of E-A Automation Systems Ltd (a member-firm of the Elliott-Automation Group), and it involved design studies which forecast considerable savings by the reduction of waste material.

Satisfactory operation began in February of this year, and although sufficient evidence is not yet available in this interim report to substantiate fully that the predicted savings are being realised, the steel manufacturers do not doubt that the expected savings will in fact be achieved.

The following is a brief outline of the problem and the method adopted for its solution.

Samuel Fox & Co Ltd roll billets of high-quality steel to lengths of up to 450 feet (137 m) before cutting them to customers' requirements. Since the steel is largely to special order, the billets must be cut to produce minimum wastage within the limits of the customers' specification and of the length as finally rolled. The problem is complicated by the layout of the mill, which necessitates the use of cutting at two or three points.

The complete problem falls into four parts: first, the measurement of billet length; second, the calculation of optimum cutting points; third, the transmission and display of this information to operators; and finally, the recording of data for office purposes.

Special Computer Requirements

This problem has many aspects which indicate the great advantages that can be attained by the use of a digital computing system. The computation has to be fast enough not to hold up the billets on the track; a self-calibrating length measurement system is required; and since a number of billets can be on the track at the same time, considerable capacity for the storage of information is required.

The joint study of this situation already mentioned showed that there was ample economic justification for a computer to optimise the cutting, and an order for such a system was therefore placed. The system has been designed to include the Panellit 609 Information System which incorporates the Elliott 803 general-purpose computer.

The measurement of length is obtained by a self-calibrating pulse-counting system which compensates for the wear on the mill rolls. The presence or absence of the billet is detected by lead sulphide detectors which have the correct spectral response to detect even the billets which have been delayed at an earlier stage of rolling and have therefore cooled to 400 or 500 deg C.

The customers' order is set up on a panel controlled by the mill foreman. This method of input was chosen in order to maintain the personal responsibility of the foreman for the running of the mill. The order may specify for the final billet (a) a fixed length; (b) a limited continuous range; or (c) a range consisting of a series of steps. The computer must calculate the optimum cutting points to satisfy the customer's requirements within the mill operating conditions and must also make allowance for the required test pieces, as well as making statistical allowances for the variability of the stops at each saw and shear. This calculation takes less than a second, and the information for the operators to use in setting their shears is therefore available within one second of the billet leaving the final mill. Most of this information is however normally stored in the computer until it is called for by the operator.

Each operator has a display panel on which information relating to the billet that he is about to cut up is caused to be displayed by the operation of a demand button, and checks are provided in the computer to ensure that the billet the operator is cutting corresponds with the one displayed on his panel. This is only one of a comprehensive series of checks in the computer programme that ensure that any abnormalities in the operation of the system are rapidly detected.

A Flexible System

One of the advantages of the stored programme of the 803 computer is that changes in mill or system operation can be incorporated with very little trouble at any stage of the design or after the system has been installed. The manual operations retained in this system can, of course, be replaced by automatic links when the system has been proved in practice if this should appear to give further gains.

An interesting addition to the foregoing report is the news recently received from Louisiana, U S A, that the Elliott 803 computer installed there as the data processing unit of the Panellit 609 Information and Computing System in a Gulf States Utilities power station has completed 4 200 hours of continuous operation without a single failure of any sort. Both Elliott Brothers (London) Ltd, who made the computer, and Panellit Ltd, who designed and supplied the Panellit 609 System are members of the Elliott-Automation Group.

This record run of 4 200 hours of non-stop operation is probably the longest continuous operation of a computer ever recorded.

A similar Panellit 609 System, exhibited at the British Trade Fair in Moscow, has been bought by the Committee for Complex Automation in the Chemical Industry for a major chemical plant in the U S S R.

There are two Panellit 609 Systems in operation in the U K. One is at the nuclear power station at Calder Hall and the other is the steel rolling mill installation described above. Seven other Panellit 609 Systems are in operation in the U S A and several are on order for countries in Europe.

Production of Hoover 'Keymatic' Washing Machines

THE new Hoover 'Keymatic' washing machine, first introduced at the Ideal Home Exhibition in London last March,* incorporates a number of new features which can justly be described as revolutionary. With such an outstandingly different design, the Hoover technicians were faced with the problem that it was impossible to develop its production from any existing Hoover Model because the concept of the 'Keymatic' is so advanced that there is no real basis for comparison. In fact, the only component which it has in common with any previous model is the rear pair of castors !

The production lines had therefore to be planned from the beginning, and this has led to the development at the Hoover (Washing Machines) Ltd factory at Merthyr Tydfil, in Wales, of a new plant costing £2 million and introducing production techniques never before used in this field. The result is claimed by the firm to be the most advanced production plant in Europe for domestic washing machines.

Models for World Markets

The description which follows applies specifically to the new 'Keymatic' production line which is housed in one of the two factories at Merthyr Tydfil, but it should be noted that at the present time seven types of washing machines are produced in the two factories, which together have an area of about 500 000 square feet (46 450 m^2). Another important aspect is that each week the production of the various machines may incorporate up to 60 or 70 variations to suit the different voltages, conditions and specifications in up to 100 countries throughout the world where Hoover washing machines are sold. During 1960, Hoover Ltd, from the Merthyr Tydfil factories, were responsible for 75 per cent of the total British exports of washing machines.

Coming back to the production line itself, which is the main subject of this story, the essential differences between this and conventional plants are apparent at the outset. First impressions are that the huge metal-finishing section looks more like part of a chemical processing plant. The press and fabrication section has a closer affinity with motor-car body manufacture than with traditional domestic appliance manufacture. The electrical section bears similarities with techniques in the fields of computer and accounting machine production.

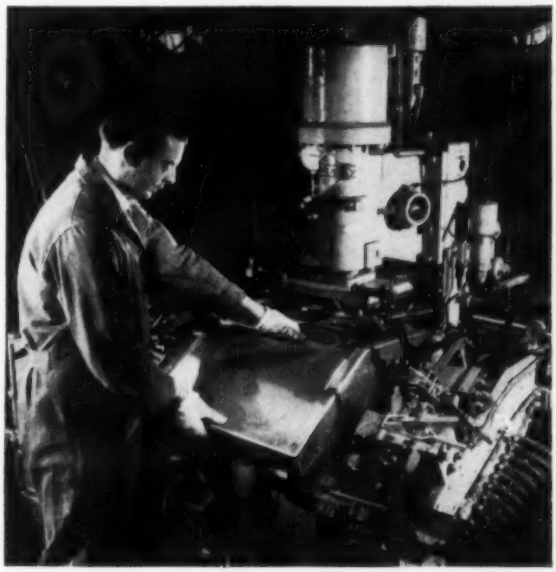
The sheet steel first goes through a Drawcote plant which applies a compound to facilitate the subsequent press operations. Specially imported from America, this plant is the only one of its kind in operation in the U K.

The four main press lines make the two halves for the inner and outer tubs, the main operation being done on 200-ton (203 200 kg) triple-action presses. Running straight on from the main press shop is another miscellaneous press shop where all the other large pressings, mainly panels, are produced. There are a number of special set-ups, including automatic transfer and handling through the press for making the shell; a special arrangement for extruding the neck on a cone-shaped component after pressing; and the use of a special rotary indexing fixture tied into the press cycle to produce the perforations in the inner tub.

Complex Welding Equipment

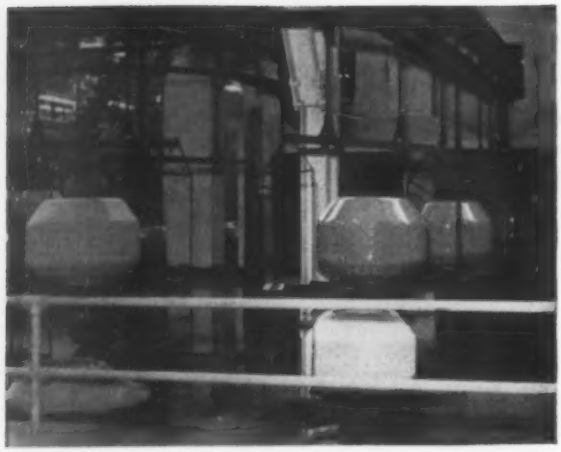
The design of the 'Keymatic' calls for such complex fabrication that special-purpose multi-spot resistance welding equipment could provide the only practicable answer. Typical of the welding lines is the one for assembling the lower half of the outer tub. The assembly passes through 13 machines, of which no less than six are special-purpose multi-spot welders. Altogether some 120 spot welds are applied. Another special line welds the base assembly. The main machine in this line carries out 32 spot welds in a single cycle. A third welding line assembles the other frame members, dealing with both right-hand and left-hand members.

In an adjacent section there is another special multi-spot welder in which the complete shell of the 'Keymatic'



Fabricating and welding front shell panels for the Hoover 'Keymatic'

* THE BEAMA JOURNAL **67**, No 2. pp 67–70



This picture shows the tubs entering and leaving the porcelain ovens

is assembled. Another special technique adopted here is the use of an Aerograph spraying machine to apply zinc-rich primer to the mating faces prior to welding, as protection against corrosion. Multi-welding is also used on the door assembly.

Altogether there are some 34 welding machines in the fabricating section, of which 14 are specially designed multi-spot welding presses.

All the welding equipment has been built and supplied by the British Federal Welder & Machine Co Ltd and Sciaky Electric Welding Machines Ltd.

Advanced Metal Finishing

After completion of these welded sub-assemblies, all parts are put through appropriate metal-finishing processes. Here again, the metal-finishing equipment was laid down specifically to meet the requirements of the 'Keymatic' machine and is very much more comprehensive than any hitherto installed at Merthyr. Indeed, for the type of work, it is among the most advanced metal-finishing shops in Europe. There is an automatic phosphating plant; three electrostatic painting lines and a dip plant; an Alochrome plant; and a special automatic spray pickling plant. All controls are centralised in a main control room.

The electrostatic painting lines are worthy of a special note in passing. Like the rest of the plant, they are completely automatic and have no human operators, but the points of interest are that the paint itself is given a positive charge, while the metal parts travelling through the booths on the conveyor are negatively charged.

This technique results in an almost complete absence of 'over-spray' and in fact ensures something like 80 per cent effective utilisation of the paint and 100 per cent coverage of the metal parts.

Another innovation is the introduction of porcelain enamelling as a finish for the two halves of the outer tub and the inner tub. There is automatic spraying of the slurry, followed by drying and, finally, fusing in a continuous furnace.

Special Assembly Techniques

Naturally enough, the most dramatic part of production is the main assembly line. Very special assembly techniques have had to be devised to overcome the difficulties of putting together this new and highly complicated design.

The line can be subdivided into four main sections: tub assembly; frame assembly; main assembly, including wiring, shell doors, and so on; and final test. Finally, transit straps are fitted and the machine is off-loaded and packed.

Reference to the description of the machine itself in our last issue will explain two of the major problems facing the engineers who planned the assembly line. First, the design of the 'Keymatic' is such that the tub assembly is not rigidly attached to the supporting frame. It is a fairly heavy assembly, made deliberately heavier by the introduction of a damping ring, but nevertheless it is flexibly mounted on the frame and is held on a suspension wire and four springs. The major operations on the tub assembly have to be carried out on its underside.

The second feature is that, instead of first building a frame and then putting the assembly into it, the reverse actually happens. The 'Keymatic' is extremely compact and yet it contains considerable mechanism, including the electrics for the programming system. This quite exceptional compactness could only be achieved by taking a bold unorthodox approach towards design.

Because of the design of the suspended tub assembly, it has to be assembled in an inverted position. This is the first operation on the assembly line, using a special tub assembly pallet. This is more than an ordinary pallet and is, in fact, quite a costly assembly rig.

The work then has to be turned into its normal upright position for the remaining assembly operations. A most ingenious Hoover-designed arrangement on the line turns the work over and simultaneously changes pallets. At the same time the now empty tub-assembly pallet is returned to the beginning of the line for re-loading. An unwieldy load weighing some 130 lb (59 kg) is thus being handled mechanically and at the same time the pallets are being re-circulated.

The tub assemblies undergoing initial welding on semi-automatic, multi-spot welding machines. The machine on the right is welding the 'cone' to the outer tub

Another special section of the line carries out a static water test on the tub. This is at an early part of the line when the minimum amount of work on the tub has been done, and so saves unnecessary assembly if there should be a fault. The frame is assembled round the tub, and the remaining final assembly operations are carried out.

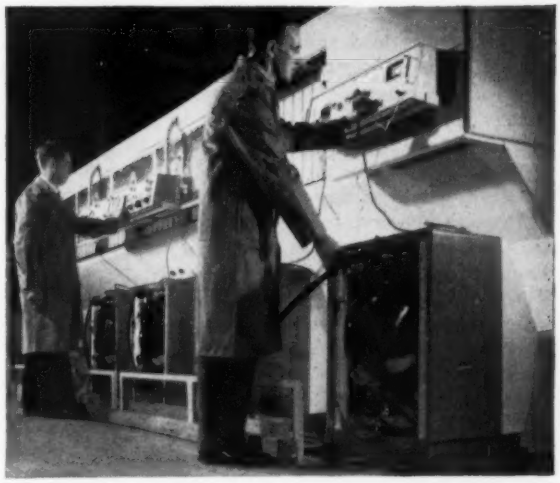
The comprehensive test section includes a special arrangement to test the automatic filling device which is one of the features of the 'Keymatic' and, of course, it is necessary to test each 'Keymatic' for its programming.

It will be recalled from the earlier description already referred to in this article that the normal cycle of the 'Keymatic', comprising washing, rinsing and spin drying, may take some 20 minutes. Special techniques have been devised for the production line by which the machine's complete programme can be tested throughout its full sequence in a few minutes.

As the machines are carried by the conveyor into the test area, they come opposite a series of test panels also moving in synchronisation with the conveyor. Each panel carries mains supply terminals from which any voltage can be selected to suit the requirements of the various countries for which the machines are intended. A special keyplate is used which covers the complete operating cycle in a rapid sequence, while fully automatic testing equipment records on central instrument panels any faults in the moving line of completed machines.

Finally, the transit straps are fitted, the hose connections are assembled, the rear panel is put on, and the line then leads straight on, via a roller conveyor, for packing.

Here again a special turnover fixture is used. The whole pack is turned through 90° and then horizontally through a right angle turn so that it is facing the despatch bay, where an automatic banding machine applies and fastens the steel bands which secure the top and bottom of the carton. Finally it is handled by another turnover fixture which brings it the right way up. The completed pack then travels down a small gravity slope into the despatch bay for shipment to the home market and all over the world.



The completed 'Keymatics' pass along the final testing conveyor where the earth continuity and the washing programme sequence of each machine are tested, going through the entire washing cycle in a few minutes

One final statistic: it is stated that, taking an average of all types, the Merthyr Tydfil factories produce a Hoover washing machine every 12 seconds !

'Open Days' at the N P L

THE annual 'Open Days' of the National Physical Laboratory at Teddington, near London, not only give visitors an opportunity to see the vast amount of work that is carried on there, but they also provide an occasion to discuss their own problems with the staff and the ways in which the N P L can be of help.

The N P L, which was founded in 1900, is one of the oldest of the great national standardising laboratories. For the first 18 years of its existence it was controlled by the Royal Society and has since been the responsibility of the Department of Scientific and Industrial Research. The aim of the Laboratory is to serve science and industry by undertaking basic and applied research, establishing and maintaining standards and units, and carrying out special studies, tests and calibrations.

As a result of reorganisation and expansion the high-voltage test equipment is being transferred to the Central Electricity Generating Board's laboratory at Leatherhead, where it will be used in close co-operation with the E R A for investigating high-voltage problems. A new Van de Graaf generator is to be housed in the old high-voltage building and will be used for work associated with radiology standards. Other new equipment includes a new microwave source for the production of submillimetre electromagnetic waves by harmonic generation from cold cathode arcs, and a microwave mekometer for the measurement of long distances by using a high-beam polarisation modulated at 9 300 Mc/s.

The work of the Autonomics Division (formerly Control Mechanisms and Electronics) falls into four groups. These cover process control, automatic pattern recognition, automatic processing of natural languages, and the extension of digital computing techniques.

Over the last two years the Division has been investigating the thin-film cryotron as a computing element. This type of cryotron utilises the low-temperature

phenomenon of superconductivity, exhibited by certain metals such as lead and tin which lose their electrical resistance at a temperature of a few degrees absolute. If a suitable magnetic field is applied, the resistance is rapidly restored, and it is possible to switch cryotrons in and out of the resistive state 1 000 million times a second. As the films are very tiny, a computer of 10^7 cryotrons would occupy only about a cubic foot (28 dm^3).

The thin-film cryotron is made up of a tin strip which acts as the gate or switch conductor, and a lead strip. The tin and lead strips are separated by a film of insulation, such as silicon monoxide, and each cryotron is further insulated from the others by a lead film which acts as a screen. As the tin film gate is a superconductor, a current will circulate around it indefinitely, but when a magnetising force is applied by passing a current through the lead strip, the resistance in the gate is restored and the stored information is thus released.

A special plant has been developed for making these cryotron assemblies. The method is by deposition of the metal in the form of a vapour through a mask and under a very high vacuum. Residual gases present in the evaporative plant are reduced by the use of a liquid nitrogen trap and a titanium getter. The plant at the N P L can handle up to seven layers without breaking the vacuum. At present a vacuum of 10^{-6} mm is used, but it is hoped that a higher vacuum will give still better results.

There are still many problems to be solved before the use of cryotrons becomes a practicable proposition. The speed of switching is dependent on film purity and structure, and the main difficulty lies in solving the problem of reproducing large numbers of cryotrons with pure films of tin and lead. The low temperature can be maintained by the use of liquid helium and this presents no problems.

The Study of Mechanical Translation

The mechanical translation of scientific Russian into English is also being studied by the Division. A Russian-English dictionary is recorded on punched cards, and when a term is inserted in the machine all the English equivalent terms are selected. Since the machine is capable of splitting text words and interpreting affixes, a Russian article can now be mechanically translated into sensible English. Up to the present, the words have to be fed in manually, but when the automatic recognition of characters has been sufficiently developed, the machine will be able to read and translate Russian texts automatically.

Other interesting work in progress in this Division is that of investigating the mechanical compilation of a scientific Thesaurus. The method used is the grouping of words on the basis of a statistical analysis of the use of words in the published abstracts of scientific articles. If this work is successful it will be of immense value in the indexing of science papers and in the revival of information which would otherwise be unrecorded under the present systems of indexing.

The Basic Physics Division has been concerned with experiments on solids at extremely high pressures. New apparatus has been made with which pressures in the order of 100 000 atmospheres (103 320 kg/cm^2) can be produced at temperatures between—200 and 2 000 deg C. The high temperatures are obtained by the electrical heating of carbon or metal sleeves surrounding the sample; the low temperature is maintained by means of liquid nitrogen circulated through hollow rings around the anvil. The apparatus is ideally suitable for making electrical conductivity measurements, as the loading anvils serve as ready-made contacts.

Physical changes occur in solids when under very high pressures, and semiconducting and insulating materials can become metallic. An example is the abrupt change from the semiconducting to the conducting state at 30 000 atmospheres (30 966 kg/cm^2) at room temperature of indium antimonide.

The N P L has now been successful in making coesite and diamond—the first time this has been achieved in this country. The conditions required for the formation of diamond are 80 000 atmospheres (82 660 kg/cm^2) and 2 000 deg C when using nickel as a catalyst. The development of future apparatus will enable optical and X-ray examinations to be made of the atomic structure of samples under pressures up to 30 000 atmospheres (30 966 kg/cm^2), and also to study the dielectric properties of solids and liquids up to 12 000 atmospheres (12 400 kg/cm^2).

Problems in Aerodynamics

As well as problems associated with aircraft design, the Aerodynamics Division is also investigating problems of wind loading of buildings and bridges. One of these projects is concerned with aerodynamic investigations for the new bridge across the River Severn in the West of England. As the designers have departed from the conventional truss-type stiffening girders in favour of girders of a sheeted-in box type section, a large number of tests are at present being carried out in order to find the best shape for the outer edges. The new 500 ft (152 m) high microwave transmitting tower to be erected in London for the British Post Office is also under stability investigation by means of an 8 ft (244 cm) scale model.

Closed-circuit television is being used in the Compressed Air Tunnel to observe the behaviour of swept wings at high Reynolds numbers. The camera is mounted in a case which has to withstand the pressure in the tunnel, but is so designed so that the camera itself is at normal atmospheric pressure. Remote control of the camera enables any part of the wing section to be observed.

Traffic noise is another problem which is being studied by the Acoustics Section of the Applied Physics Division. The object of the work, which is being undertaken in co-operation with laboratories in other countries, is to determine the form of sound level meter best able to measure motor vehicle noise. A preliminary investigation in co-operation with the Ministry of Transport has been made into the probable effects of the surroundings on the readings of the sound level meter.

The Standards Division maintains the national standards such as light, weight, mass, and the electrical units, and it undertakes the calibration and comparison of instruments and measuring apparatus used by industry. It is also concerned with research in relation to determining standards and in improving the accuracy of measurement of basic and derived quantities.

The Berkeley Nuclear Laboratories

THE BERKELEY NUCLEAR LABORATORIES, which were officially opened in April this year, form a branch of the Research and Development Department of the Central Electricity Generating Board. They have been established to carry out the majority of the Board's research and development work arising from the civil nuclear power programme in Great Britain.

The Research and Development Department of the Board was created in 1958 and one of its first objectives was to provide a comprehensive nuclear power laboratory. The Board was already committed to a capital investment in nuclear power amounting to several hundred million pounds sterling and was, potentially, the owner and operator of the largest assembly of nuclear power plant in the world. The need for nuclear power research facilities arose from the Board's implicit responsibility to develop nuclear power as an efficient, economic and reliable source of electricity supply.

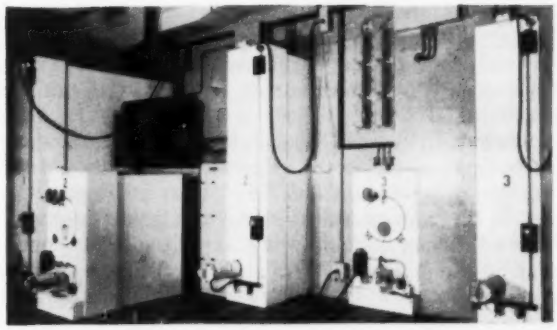
There were a number of clear advantages in building the laboratories close to one of the first civil nuclear power generating stations to be commissioned, and of the possible sites, Berkeley in Gloucestershire was the most favourable. Construction of the laboratories began in October 1959.

The Role of the Laboratories

Berkeley Nuclear Laboratories have been designed as a comprehensive nuclear power research facility, and the first detailed programme of work has been determined by the fact that the present civil nuclear power programme is centred on the natural uranium graphite-moderated gas-cooled reactor. The nuclear stations now under construction in Britain are the outcome of extensive knowledge and experience of nuclear plant, but the fact remains that the science and technology of nuclear power is comparatively new and there are substantial technical advances and economic gains to be made. These require (among other things) intensive research and development work, mainly concerning the nuclear reactor, in the fields of materials, physics and engineering.

A central problem, and certainly one of the most important, is the behaviour of reactor materials which have to operate under hitherto unknown conditions of intense nuclear radiations.

First, there is the damage due to the bombardment by fast neutrons of the permanent constructional materials of the reactor—principally steel and graphite. Second, there is the problem of radiation damage to the fuel elements. It is economically essential that the reactor structure shall give the maximum length of service and that the life of fuel elements shall not be curtailed by radiation damage before the available energy in the uranium has been released.



A rear view of the caves with the massive concrete doors which slide out to give access to the maintenance area

The Materials Division of the Laboratories is concerned primarily with radiation damage problems and will direct its efforts towards improving the understanding of radiation damage phenomena, predicting the behaviour of materials and introducing improved materials for reactors and fuel elements. Materials from an operating reactor are inevitably in a highly radioactive condition, and their examination during the study of radiation damage requires special facilities. Some of the most advanced equipment in the world is installed for this purpose in the Berkeley Nuclear Laboratories.

A second division of the Laboratories is concerned with the physics aspects of nuclear power generation. The physics of the reactor core need further study and this will be made, on the laboratory scale, with exponential assemblies of graphite and fuel elements and on the plant scale during the normal commissioning of the Board's nuclear power stations, when staff from the Laboratories will provide assistance.

Other important problems arise in nuclear instrumentation, where much remains to be done in developing more reliable and accurate methods of measurement. For example, at Berkeley there is to be a study of high energy gamma ray dosimetry and intermediate energy neutron measurements, both of which have an important bearing on nuclear power plants. The Physics Division is also responsible for a very extensive programme of measurements on graphite samples from all the Board's reactors. This is designed to establish the integrity of reactor cores and to ensure that the maximum life consistent with complete safety is obtained from each reactor.

A variety of engineering problems is involved in the development of nuclear power and many of these will be examined by the Engneering Division of the Laboratories. In particular, the mechanical performance of fuel elements under operating conditions needs further

study, and even small improvements in the heat transfer properties of fuel elements offer rewarding gains from nuclear plants. Berkeley will have rigs for studying, under full reactor conditions of temperature and pressure, both the heat transfer properties and the mechanical endurance of fuel elements. The mechanical aspects of fuel element handling, control systems and instrumentation will be given detailed attention. One section will deal with pressure circuit components, studying the complex stress systems involved and making the required mechanical tests.

The handling of radioactive materials poses many special problems and elaborate precautions must be taken to ensure that all operations are carried out in a safe manner.

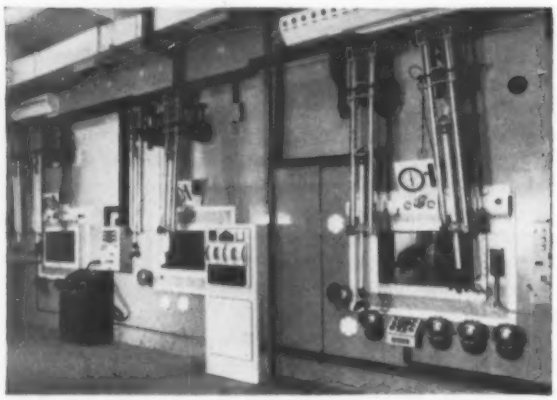
The Health Physics Group of the Laboratories provides an essential service in this respect and in addition works in close collaboration with the nuclear instrumentation section on fundamental problems in radiation dosimetry.

Fundamental scientific work as well as technological studies are necessarily included in all the foregoing aspects of the work at Berkeley. The programme is directed essentially towards improving the efficiency and reliability of nuclear generation while reducing costs and maintaining the highest standards of safety.

Laboratory Design and Research Work

The Laboratories share a common boundary with the Berkeley nuclear power station. Both establishments belong to the Generating Board but administratively they are quite separate. Radioactive materials are handled in the shielded area and the laboratory wing, which are on the North side; the administration and office block links these areas with the engineering hall which lies to the South. In addition there is a boiler house and a maintenance block. The total floor area of the Laboratories is about 100 000 square feet (9 290 m^2) and the cost of erection and the initial capital equipment amounted to about £2 million.

There are a number of special features about the shielded area and the laboratory wing. Normal access to them is through the change rooms in which members of the staff put on protective clothing and ultimately make sure that they are free from radioactive contamination before leaving. All protective clothing is washed in the laundry which is adjacent to the change rooms. Radioactive facilities require continuous ventilation and at Berkeley an air-conditioning system supplies warm fresh air to the buildings and extracts it through extremely efficient filters which remove any possible radioactivity before discharge into the atmosphere through a 75 ft (23 m) chimney. This ventilation system is designed to maintain a slightly negative pressure inside the radioactive facilities so that, in the unlikely event of a release of radioactive materials within the buildings, the chances of their escape into the atmosphere are negligible. Furthermore, all drains from the radioactive areas lead to hold-up tanks where the effluent can be effectively freed from any traces of radioactivity before final discharge.



A front view of the caves showing the observation windows and the remotely-controlled manually-operated manipulators

The Shielded Area

The shielded area is approximately 180 feet (55 m) long by 100 feet (30·5 m) wide. It has been designed essentially to provide facilities for the Materials Division to undertake post-irradiation examination of fuel elements and test specimens, such as steel, from reactors. The layout and equipment have therefore been designed to receive fuel elements in transport flasks containing up to one million curies of radioactive material and to carry out examinations which involve the reduction to specimen whose activity is sometimes less than one curie.

At present, fuel elements consist of cylindrical rods of uranium, about 1 inch (25·4 mm) in diameter and of various lengths between 12 and 40 inches (30·4 and 101·6 cm), encased in magnesium alloy cans. They have helical fins and longitudinal splitter vanes to improve heat transfer characteristics. After removal from a reactor each complete element is sealed in an outer can, up to 30 of which are loaded into large shielded flasks for transport to the Laboratories. The flasks (approximately 8 feet cubes (2·4 m) weigh about 50 tons (50 802 kg) each and are off-loaded by a crane and deposited at the Laboratories in the pond which is 20 feet (6·1 m) square by 29 feet (8·8 m) deep. When required for examination, a fuel element is removed from the flask under water and taken by a conveyor through a shielded tunnel into the first of a suite of three caves.

The caves are formed of mild steel 0·5 in (12·7 mm) thick with massive outer concrete walls over 5 feet (1·5 m) thick. They are each about 9 feet (2·7 m) square and 14 feet (4·3 m) high, and are separated by power driven sliding partitions 2 ft 3 in (69 cm) thick. Observation from the front is through windows formed of lead glass filled with a zinc bromide solution. At the rear, giving access to the maintenance area, are massive concrete sliding doors.

The caves have been designed so that while the dose rates in the operating area remain well below permissible levels, any one cave may contain an activity of 50 000 curies with 10 000 curies in each of the other two caves. All operations within the caves are carried out by remote control and each cave has its own manually-operated remotely-controlled manipulator. In addition, there is a power-driven manipulator which runs on overhead

rails and can be used in any of the three caves. This power manipulator can be connected to the emergency electrical system in the event of a mains supply failure.

In the first cave the fuel element is removed from its outer can and is inspected visually. From there it is transferred to the second cave, which is equipped for metrology and radiographic examination. If an inspection is required to detect minute cracks in the fuel element can, it is transferred to the third cave which is equipped with modified leak detection equipment. Following these procedures, the fuel element is returned to the first cave where two cutting machines remove the alloy can. The uranium bar can now be sectioned and small pieces transferred to the third cave for the preparation, using a milling machine, of specimens for mechanical tests and metallographic examinations.

From the cave suite, specimens are transported by a shielded 'railway' to a suite of nine cells running at right angles to the caves. Eight of the cells are 5 feet (1·5 m) wide, 4·5 feet (1·4 m) deep and 6 feet (1·8 m) high and are separated from one another by fixed heavy concrete partitions 20 inches (51 cm) thick. The ninth cell is of double width. The shielding at the front of the cell consists of a wall of heavy concrete 2 feet (61 cm) thick, 2 ft 9 in (84 cm) high on which is a lead wall 10 in (25·4 cm) thick with inset lead glass viewing windows. The roof is of steel, 10 in (25·4 cm) thick, pierced to take manipulators and the rear wall is of normal concrete 4 feet (1·22 m) thick with removable plug doors. The shielding ensures that acceptably low dose rates are received in the operating area when one cell contains 500 curies, with 100 curies in each of the other cells.

Two cells are used for machining operations on test specimens; a third houses an Instron tensile testing machine, and yet another is employed for metrology. The double cell is devoted to the steel specimen monitoring programme. In another cell there is an encapsulating rig for sealing specimens in silica and several furnaces for subsequent heat treatments. Finally, there are two general purpose cells in which short-term experiments are carried out, and a cell which is used for storage and general decontamination work.

In line with the cells are a number of lead box suites designed for work with specimens whose activity is less than one curie. These comprise sealed steel boxes equipped with Perspex windows, each surrounded by lead, 4 to 10 in (10 to 25 cm) thick, fitted with flush lead-glass windows. Typical uses for lead boxes are metallographic examination and testing and small scale physical chemistry. The lead boxes are contained in cubicles with access from the cell operating area and they are designed for operation from at least two sides, in contrast to the cells where operation is only possible from the front face.

Behind the cells and lead boxes and to the rear of the caves are maintenance areas to which access is gained via an additional change room. A decontamination bay, a maintenance workshop and a first-aid room lead off this area, which is also equipped with a special change room for pressurised suit work should this ever be required for duties involving grossly contaminated equipment.

Generally, all the walls, ceilings and other surfaces are finished with a cold-cured epoxy resin paint and in certain areas a strippable coat has been added. One ventilation system serves the caves and cells, while a separate system serves the operating areas. Before discharge to atmosphere, the air passes through several filters: a fireproof filter inside the cave, a flameproof absolute filter immediately outside, and a second flameproof absolute filter in the plant room. Similar precautions are taken with the gaseous effluent from the cells, lead boxes and operating areas.

Liquid effluent from the caves, workshop, decontamination centre and pressurised-suit change-room is regarded as being of medium activity and is treated by flocculation precipitation before being mixed with low-activity effluent from all other areas in this wing. The low-activity effluent may be treated similarly. The radioactive content of the effluent as discharged from the Laboratories will always be negligible.

The Laboratory Wing

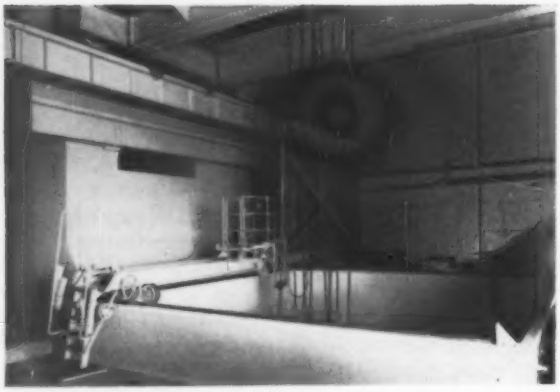
This wing, which runs at right angles to the shielded area, is a three-storey building providing laboratory accommodation on the ground and second floors, with all services and ventilation ducting on the mezzanine floor. While the shielded area is designed for post-irradiation examinations and is concerned predominantly with operational research, the work in the Laboratory Wing is centred more on the necessary fundamental investigations into the behaviour of reactor materials. This wing provides facilities chiefly for the Materials Division but it also houses the solid state physics and the graphite sections of the Physics Division.

On the ground floor accommodation is provided for an analytical chemistry laboratory, two general metallurgy laboratories, a hazard chemistry laboratory (equipped with its own special change room), laboratories for work in solid state physics and a laboratory shared between health physics and nuclear instrumentation. Finally there is a balance room, a store room, and a glass blowers' workshop.

The second floor houses the graphite laboratory and laboratories for electron microscopy, physical chemistry, X-ray diffraction, metallography, spectrometry and general metallurgy. There are also photographic dark rooms, a dark operations room, a furnace and fabrication facility, a graphite furnace room, and a small general workshop for work which must be carried out within the radioactive areas.

The analytical chemistry facilities have been designed mainly to determine in irradiated fuel the degree of utilisation of fissile materials and the levels of trace impurities; they also provide a general analytical service for the Laboratories as a whole. Specimens with a radioactive content of up to one curie can be handled, and much of the work is carried out in specially designed fume cupboards. The hazard chemistry laboratory, equipped with its separate change room, is designed for physical chemistry research at higher levels of radioactivity, and the equipment includes fume cupboards and glove boxes for handling alpha-active materials.

In the physical chemistry laboratory an important



The pond into which flasks, each holding up to 30 fuel elements, are deposited and from which they are removed for examination through an under-water tunnel

part of the work is the study of high temperature oxidation atmospheres of materials such as uranium and magnesium alloys in carbon dioxide. An electron diffraction unit, an X-ray micro-probe analyser and a mass spectrometer are provided for use in this work.

In the three general metallurgy laboratories the emphasis is on the metallurgical properties and behaviour of reactor materials. Planned investigations include the growing of single crystals of uranium and associated electron microscopy studies; work on reactor materials using an Instron tensile testing machine; the measurement of bowing deformation in uranium under low loads; studies of creep in graphite at low temperatures, and of the mechanism of the initiation and development of leak paths in fuel element canning materials. Two electron microscopes are associated with this work together with ancillary equipment including an evaporator and an ultra-microtome.

The X-ray and Graphite Laboratories

The X-ray laboratory is equipped with an X-ray diffractometer, general apparatus for powder crystallography, a fine focus X-ray set, and an electron beam micro-analyser. A metallographic laboratory is equipped to prepare specimens for subsequent examination and photography of microstructure. Arc, high frequency, and general heat treatment furnaces, together with a rolling mill, a swaging machine and a 50-ton press are installed in the furnace and fabrication room, and a special high temperature furnace (operating at temperatures up to 3 000 deg C) is installed in the graphite furnace room.

The graphite laboratory of the Physics Division provides the necessary service for the Board's reactor graphite monitoring programme and is also concerned with more fundamental studies of the behaviour of graphite under irradiation. In each of the Board's reactors there are several thousand graphite specimens throughout the core which will be removed in accordance with a predetermined programme and measured to determine changes in weight (due to oxidation), physical dimensions (due to Wigner growth), and stored energy. Associated fundamental research is concerned with the properties of irradiated and unirradiated graphite, thermal annealing, stress relaxation, and radiation damage.

The Engineering Hall

The Engineering Hall, which is 160 feet (48·8 m) long, 115 feet (35 m) wide and 60 feet (18·3 m) high, provides accommodation for the main workshops of the establishment, the large rigs of the Engineering Division and for the numerous laboratories of both the Physics and Engineering Divisions.

The Physics Division has laboratories for radioactive counting, reactor physics, health physics, and nuclear instrumentation, together with instrument and electronics workshops and a photographic dark room. The radioactive counting laboratory, which is shared by the reactor physics and nuclear instrumentation sections, is equipped with a wide range of counting equipment. In one corner of this laboratory a small area has been partitioned off as an isotope laboratory and fitted with a fume cupboard, where small unsealed sources of up to one millicurie are handled. The reactor physics laboratory serves the needs of the two exponential assemblies to be erected on the main floor of the Engineering Hall, the immediate purpose of which is to investigate absorber design and the effect of vacancies in reactor lattices.

The nuclear instrumentation laboratory is chiefly concerned with the development of improved methods of radiation detection. Problems under investigation include the dosimetry of high energy (6MeV) gamma radiation, fast neutron dosimetry and spectrometry methods, burst cartridge detection, and for shielding measuremetry to be used in shielding experiments during the commissioning of the Board's reactors.

On the main floor of the Engineering Hall are two rigs for the investigation of the heat transfer properties of fuel elements. The rigs contain fuel element cans fitted with electrical heaters and employ atmospheric air as a coolant. A closed-circuit pressurised rig, using carbon dioxide as the coolant, is shortly to be added for heat transfer studies under reactor conditions, and a rig for endurance tests on fuel elements contains a dummy reactor channel in which complete fuel elements can be tested. A further facility is a visual flow rig in which water, loaded with a fluorescent dye, is pumped past a fuel element held in a perspex tube to demonstrate the fluid flow patterns around the element.

The problems associated with end cap welds are investigated in three rigs which have been designed for the measurement of the force required to push off an end cap under a variety of representative temperature and pressure conditions. The effects of thermal cycling in fuel elements are studied in a group of four rigs—three of which provide slow rates and one provides fast rates of thermal cycling. There are also rigs for investigating the mechanical effects of fin vibration and fuel swelling.

These new Laboratories—the latest addition to the Central Electricity Generating Board's already considerable research projects concerned with the generation, transmission and distribution of electrical energy—will make a powerful contribution to Britain's position as the leading nuclear power country in the world already won for it by the electrical manufacturing industry.

The Engineering, Marine, Welding, and Nuclear Energy Exhibition

THIS year's Engineering, Marine, Welding, and Nuclear Energy Exhibition at Olympia was probably one of the most elegant displays of engineering plant ever to be seen there. It was certainly the largest. Over 500 exhibitors occupied 275 000 square feet (25 500 m^2) of stand space.

On many of the stands were models of plant exported overseas, and it was not surprising that Mr A. I. Baker, C B E, Honorary President of the Exhibition, should comment on the export record of the industry in his speech at the opening ceremony.

He pointed out that more exports will follow 'machines that build progress wherever they go. They go to factories all over the world and especially to the great civil engineering projects which are transforming the lives of peoples in distant countries—the great steel works at Durgapur in India; hydro-electric projects in Canada and Brazil; the Tokai Mura nuclear power station in Japan; tyre factories in Russia and Roumania; the Tema harbour development and the Volta dam in Ghana'.

In this review it is not possible to describe in detail all the thousands of exhibits; instead it seeks to emphasise the trends in engineering development as revealed on the stands of BEAMA member-firms. They show that the engineering industry is, in Mr. Baker's words, 'forging ahead in a manner of which we can be proud'.

Marine Electrics

The growing acceptance of a c power on ships was emphasised by the exhibition, with many manufacturers showing alternating current equipment. Generating plant was to be seen on the stand of W. H. Allen Sons and Co Ltd. A 750 kW turbo-alternator—one of two similar units for installation in a 37 000-ton tanker—was shown with its mechanical end opened up, revealing a neat arrangement incorporating an epicyclic gear of the double-helical planetary type. With this, a very compact arrangement of plant is possible, saving both weight and space. The alternator is of a conventional marine type and is designed to operate continuously in an engine room temperature of 110 deg F (43 deg C). The turbine, which runs at 13 500 rev/min, is designed for steam at 575 lb/in^2 (40·4 kg/cm^2) and 830 deg F (443 deg C). The gearing reduces the drive to the alternator to 1 800 rev/min, giving an output of 440 V at 60 c/s.

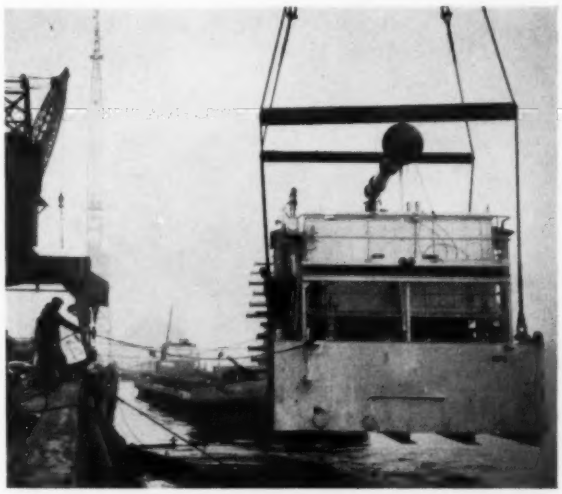
A 700 kW back-pressure marine auxiliary turbine-generator was shown by the Turbine Generator Division of A E I Ltd. This operates at similar steam conditions but the turbine runs at 8 000 rev/min. It drives a 440 V 60 c/s alternator at 1 800 rev/min through a double helical single-reduction gear box.

A 250 kW diesel-driven alternator made by W. H. Allen showed the use of dual-fuel operation. The GS37-D engine employed is of the four-stroke airless injection, compression ignition type. It is arranged for continuous operation on natural gas with only a minimum requirement for liquid pilot fuel, which in this case will be crude oil. To facilitate starting, the crude oil is continuously circulated through hot-water-jacket duplex filters. In keeping with the trend towards greater ease of handling, the set is arranged for remote push-button starting.

On the stand of the English Electric Co Ltd, the growing use of a c in ships was further emphasised. The main exhibit—a working display of a simulated marine a c distribution scheme in a large passenger ship—showed operation from a central control point. It demonstrated the procedure of starting alternators, synchronising, loading, and dealing with fault currents. This included the tripping-out of non-essential circuits on a timed three-stage basis, and a complete shut down with an emergency set providing power for such essentials as navigation, radio, etc.

The General Electric Co Ltd of England showed their range of hot cathode fluorescent fittings for use throughout ships (over 40 tankers and dry cargo vessels now building use the company's equipment). Also, new additions to the 'Mutac Clipper' range of 250 V a c switches were to be seen. Only three sizes of box are now necessary to give a range from 1 to 12 gang-switches.

Direct current, however, is still used on many existing ships. In the cargo winches shown by Laurence, Scott and Electromotors Ltd, both a c and d c types were displayed. The d c machine was a self-contained version of the winch supplied originally with contactor gear arranged for deck-house mounting. All the essential features have been retained in the new model with control gear incorporated in a compact weatherproof



A sea-water evaporator manufactured by Richardsons, Westgarth bound for Abu Dhabi in the Persian Gulf

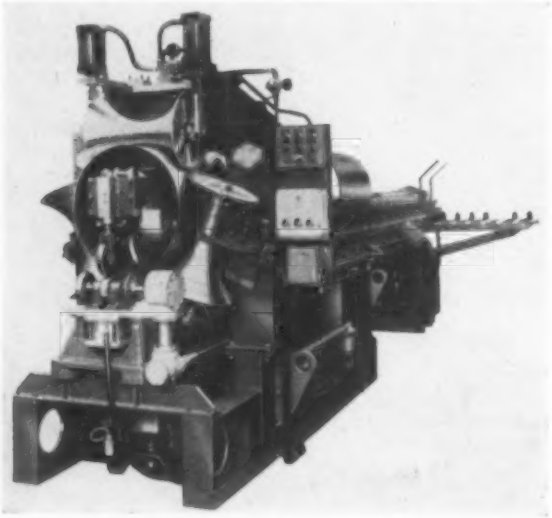
case forming part of the winch assembly. 3- and 5-ton ratings are supplied; braking is electrical except in emergencies.

The winch for ships with a c mains incorporates a light-weight motor generator set, supplying the winch motor on the Ward Leonard system. It is claimed that the performance is greatly superior to that of a winch using an induction regulator drive, and also that frequent heavy a c surges are avoided. The movement towards still higher a c voltages was to be seen in a stator suitable for voltages of up to 3·3 kV, as are now being adopted on larger ships.

Generation

Apart from marine and nuclear plant, generating equipment displayed at the exhibition illustrated the use of very large units and the methods which are being developed to take full advantage of their operating characteristics. The Turbine-Generator Division of A E I Ltd showed large-scale drawings of a 200 MW machine—one of two being built for the C E G B power station at Willington, and similar to two intended for the Hazelwood Power Station in Australia. It is hydrogen cooled with vertical coolers in separate end compartments, and the stator incorporates a system of direct water cooling.

The automatic control of large central station boilers was shown by Babcock & Wilcox Ltd. By drawings and animated diagrams the company illustrated the computer control of one of the 200 MW boilers now being installed at the West Thurrock station of the C E G B. A Ferranti Argus computer is used to provide programmed fully-automatic start-up, on-line operation, and shut-down of a 1 350 000 lb/hr (612 000 kg/hr), 2 650 lb/in² (187 kg/cm²) boiler. The computer uses solid-state components throughout and receives 173 analogue signals from transmitters and three-term controllers, and 675 digital signals from on-off devices. It also monitors approximately 150 metal-bearing temperatures. All this information will be processed and will provide an output to 194 digital drives to various relays and contactors operating boiler controls. In this way fans, heaters, coal pulverisers, burners, pumps, superheat and reheat temperatures, steam pressure, air and gas dampers, and feed, steam and drain valves will be adjusted automatically. In addition the computer will continually monitor the plant, take corrective action in emergencies, and provied a printed log of plant operations.



This British Federal machine forms and seam-welds drum bodies at the rate of 400 an hour

Nuclear Power

Illustrations of various British nuclear power stations under construction were to be seen on a number of stands. The particular steam conditions met with in these plants have led to the demand for a new range of turbines. The Turbine Generating Division of A E I, for example, were showing one of the four 3 000 rev/min 83 MW mixed-pressure machines installed at Berkeley nuclear power station. A feature of these turbines is that they are designed to run on large quantities of steam at relatively low pressure and temperature conditions, and this calls for a large exhaust area. In the A E I machines this is achieved by means of a multi-exhaust system.

The carbon dioxide circuits in the nuclear generating stations have necessitated the development of many items of specialised equipment. Aiton & Co Ltd were exhibiting corrugated piping of 18 in (45·5 cm) inside diameter for service at the Trawsfynydd station, and Richardsons, Westgarth & Co Ltd were showing a new type of bellows restraint mechanism for the same reactor.

The general requirement for remote control in these stations has led to the development of various actuators. English Electric displayed a new range of rotary electric actuators for the automatic control of valves. Three sizes of actuator provide outputs from 80 to 800 lb-ft (119 to 1 190 kg-m). Rotary motion is provided by a 440 V 3-phase 50 c/s squirrel-cage induction motor, which drives the output nut through an oil-immersed worm wheel reduction gear box. A hammer-blow effect for moving a sticking valve is given by lost-motion mechanism. This allows the motor to run up to full speed before transmitting torque to the valve spindle.

Internal Combustion Engines

The use of combined steam-turbine/gas-turbine geared main propulsion machinery developed by A E I Ltd for the Royal Navy's general purpose frigates and guided-missile ships was represented by a number of exhibits. H M S *Devonshire* is the first of the destroyers to incorporate this machinery and contains four G6 gas-turbines, two being associated with each of the vessel's main propeller shafts.

The company were also showing a model of the Gach Saran power station, which houses three L51C gas-turbines each driving a 5·5 MW salient pole generator. They supply power for the operation of two distant oil producing units, a water pumping station, and an adjacent housing estate. Models of gas turbines ordered by the Assam Oil Company to supply power for a refinery were shown by English Electric. Two sets, to run on natural gas, are now erected. The type used is

designed to operate on distillate fuels, natural gas, or crude oil. It is an open-cycle two-shaft unit that is readily transportable.

Heating

The growing demand for process heating equipment was reflected in the range of products shown by the Stanelco Process Heating Group of Standard Telephones and Cables Ltd. Shown for the first time were the G 300 Electro-Gas and the G 400 Mecho-Gas equipments for soldering, brazing and hardening. The G 300 has two work stations, each using 12 burners, which are operated alternately by means of a simple change-over lever. While one station works with the burners full on, the operator can load the jigs on the other station. The G 400 has been developed for simple process jobs where electric timing is not necessary.

The company also exhibited a number of machines using resistance heating. In this process fast local heating can be achieved by passing current directly through the workpiece. The machines have a variable voltage output and water-cooled clamps to suit the parts being heated. The technique has proved most successful on such work as stress-relieving on bends in stainless steel pipes for jet aircraft, local annealing of tubular sheathed elements, and soft soldering of fittings into paraffin tanks.

The main exhibit on the stand of Garringtons Ltd was an automatic induction heating machine designed for steel billets 1 to 2 in (2·5 to 5·1 cm) square or round, 2 to 9 in (5·1 to 22·8 cm) long. Billets are raised to a temperature of 1 250 deg C at a production rate of 2 000 lb/hr (905 kg/hr). A new feature of the heater is the continuous billet feed. This reduces current fluctuations by maintaining constant billet conditions within the heating coil. The feed system consists of a vibrator conveyor together with a double belt device, easily adjustable to suit different billet sizes.

In line with the growing need to reduce air pollution and to conserve waste heat, Babcock & Wilcox displayed waste heat boilers employing the Waagner-Biro system. These use the waste gases from the 'blow' of a converter in a steelworks to generate high-pressure saturated steam. At the same time, the temperature of the gases discharged is reduced sufficiently to permit the removal of the dirty 'fume' from the blow to meet clean air requirements. The equipment can be operated in conjunction with supplementary firing or steam accumulators and a superheater, to maintain a steam supply to turbine plant in spite of the intermittent heat cycle of converter operation.

Evaporators

Growing industrial development in the arid zones of the world has meant a demand for evaporator plant to provide water supplies there; and British exports have played a large part in providing that plant. Several examples of evaporators currently being produced were to be seen at the exhibition, together with a range of smaller evaporators for marine use.

G. & J. Weir Ltd showed a model of units recently supplied to the Government of Kuwait, Persian Gulf. The plant is for the 'multiflash' distillation of sea water and has an output of 1 million gallons (4·55 million l) per day. A P & B multistage flash evaporator under construction for service abroad was also illustrated on the stand of Aiton & Co Ltd, while Richardsons, Westgarth & Co Ltd showed a vacuum flash evaporator recently despatched to Abu Dhabi in the Persian Gulf.

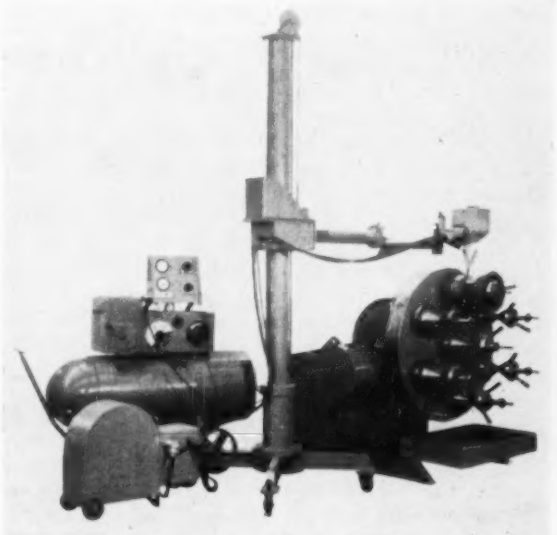
Weir showed their type F 1 two-stage flash evaporator —a 20 ton (20 321 kg) per day version of a new range of marine evaporators giving outputs of 20 to 75 tons (20 321 to 76 203 kg) per day. It is a compact unit incorporating a distilling condenser, external feed heater, brine and distillate pumps and steam-jet air ejector. Using the once-through principle of brine circulation, it also incorporates demister screens of finely-knitted Monel metal wire to prevent carry-over of water droplets with the vapour. These units are also suitable for land installations.

Another new unit shown by the company, the D 1 marine evaporator, is of the submerged type designed expressly for use in motor vessels. It employs main engine cooling water as the heating medium. Of vertical design, it also makes use of similar demister screens. Six standard sizes giving outputs between 5 and 30 tons (5 080 and 30 481 kg) per day are available.

Pumps

In the wide range of pumps displayed at the exhibition it was possible to see a general increase in capacity of most types and also the development of more robust pumps for handling liquids containing a high proportion of solids.

What is believed to be the first epicyclic gear unit for a vertical circulating water pump application in a U K power station was shown by W. H. Allen. The unit is designed to transmit 3 250 h p at 988/185·2 rev/min and it is thought that the use of this type of gearing is likely to increase in the future in view of the cost of direct-drive motors designed for large capacity slow-running pumps. The pump is one of four to be supplied to the C E G B Blyth 'B' station. It has branches of 78 in (2 m) nominal diameter and pumps 147 500 gal (670 000 l) per minute of sea water against a total head of 59·2 ft (18·1 m).



An automatic welding installation for resurfacing tractor track rollers, incorporating the Lincolnweld ML3 submerged arc unit

The use of an argon shroud in aluminium stud welding minimises porosity and atmospheric contamination. Crompton Parkinson Ltd. showed this equipment for the first time

The speed reduction gear is a vertical planetary type and the gear case is designed to support the dead weight of the motor—approximately 22 tons. The input and output shafts are flexibly coupled to the motor and pump shafts, and the self-contained lubrication system equipped with pressure switches and electric drive enables the set to be remotely controlled.

A pump designed to meet the demand for a reliable and efficient unit to deal with crude sewage, sludge, and liquids carrying solids in suspension was also shown by W. H. Allen Sons & Co. A two-blade impeller of the single entry shrouded type is used, with large unobstructed passages. The distance between the blades at all points is equal to, or more than, the width at the periphery, and care has been taken in design to avoid any projections which might trap fibrous or stringy material which would build up and cause choking. The impeller has radial cheeks front and rear which run with fine clearances against the renewable rings in the casing. To prevent grit and other abrasive material entering these clearances scraper vanes are provided. The unit displayed had 3 in (6·6 cm) diameter suction and discharge branches and passed 460 gal (2 090 l) per minute against a head of 67 ft (20·4 m) when running at 1 460 rev/min.

Worthington-Simpson Ltd showed their latest large-capacity cargo oil pump, model 10LNS22. It is a horizontal single-stage centrifugal type and handles 1 350 tons (1 372 000 kg) an hour against a pressure of 150 lb/in^2 (10·55 kg/cm^2) when run at 1 800 rev/min. The company have also extended their range of type D pumps for sump duties covering capacities up to 330 gal (1 500 l) per minute and heads up to 210 ft (64 m). The newly developed units, which are intended for use in sumps up to 10 ft (3·05 m) deep, comprise a motor (up to 10 h p) mounted on a stool holding the main thrust bearing, a sole plate, suspension pipe, shafting, and a pump end from the existing D ranges. The pumps will handle a wide variety of acids, alkalis, and slurries. Certain types are also designed to deal with liquids containing solids up to 0·5 in (1·27 cm) diameter.

Instruments

The most ambitious scheme for centralised instrumentation and control was the computer system described earlier. However, the principle of centralised instrumentation was noticeable in a number of exhibits, while much of the plant displayed was suitable for incorporation in such systems—the large-capacity water pump described above, for example.

New automatic protection panels for lower priced internal combustion engines were shown by Smiths Industrial Division. The equipment shuts down the engine if fuel or oil pressure drops, or if the coolant temperature rises excessively. The main items of equipment on the panel are a contact pressure gauge and a contacting thermometer.

Welding

A trend noticeable among the many exhibits in the separate Welding Exhibition was the greater attention paid to the needs of specialist applications—such as bridge building, storage tank construction, car assembly. Evident too was an increasing degree of automation in large specialised machines. Other developments to be seen were the use of the high welding capacities offered by 3-phase a c rectification, better designs of the various types of gas-shielded arc welding equipment, more efficient hand-welding guns, and efforts to make weld examination both easier and more thorough.

Sciaky Electric Welding Machines Ltd exhibited their MGT 4-5 fully automatic multi-head spot welding machine designed for mass production of motor passenger vehicle wheels. This type of machine has an operational output of over 400 wheels per hour and can be adjusted for various wheel sizes. Equipment developed from two MGT 4 machines is now available to weld wheels at a speed of 925 units per hour, the assembly of the wheel rim and spider and the punching and chamfering of the valve hole being automatically effected in the same set-up.

The plant is designed for operation on the patented 3-phase balanced-load principle and has a power factor of about 0·85, consuming 300 kVA. Eight spot welds only are used in the assembly of the wheel rim to the spider. These have a shear strength of 21 tons (21 337 kg), compared with the 14 tons (14 225 kg) of a wheel assembly riveted in 12 places. In addition, the spot-welded wheel is leak-proof and is therefore particularly useful for tubeless tyres. Four spots are made in the first stroke and then the wheel is automatically indexed, a further four welds added, and the complete wheel ejected by way of a chute.

On the stand of the British Federal Welder and Machine Co Ltd their latest type of fully automatic high-speed drum forming and welding equipment was to be seen. Designed for the production of 45 gal (205 l) drums, the 250 kVA machine exhibited had an output of about 400 drum bodies an hour and could be provided with a crushing roll unit to provide a completely flush internal joint suitable for lacquering. It accepts pre-cut blanks and incorporates automatic roll forming to the required drum diameter. Formed components are automatically conveyed through a conveyor section into the sizing and welding head in which the drum bodies are mash seam welded. Drum bodies up to about 42 in (1·07 m) in length will be accepted by the machine, in gauges varying from about 26 to 16 S W G (0·457 to

1·627 mm). A range of diameters can be accommodated, as the sizing roll head is designed for rapid changeover.

A portable 3-phase welding rectifier, type TPR 400, was shown by Arc Manufacturing Co Ltd. This machine incorporates a bank of silicon rectifiers, forced-draught cooled, and provides a smoothly variable output between 45 and 450 A at 25 arc volts. The company say that the rectifier provides the desired conditions for using all types of welding electrodes, particularly low-hydrogen types, including heavily loaded iron-powder electrodes, stainless steel, aluminium, copper, and nickel.

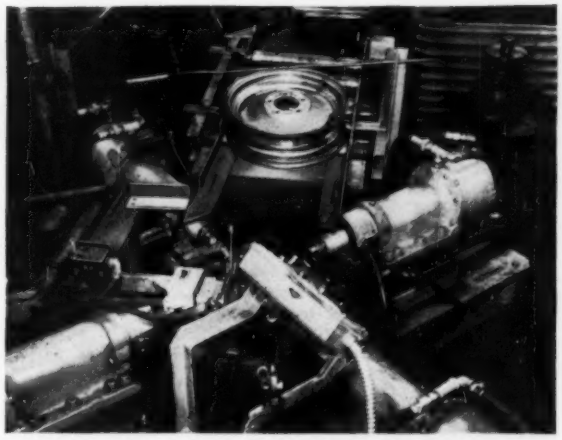
The manual Lincolnweld type ML3 (remote control) submerged-arc welding unit was also demonstrated. This is specially designed for use where the application does not permit the siting of the welding generator and the welder unit close to the actual point of welding. The remote control unit gives full control of the welding current and voltage and its compactness enables the unit to be taken into confined spaces. The equipment is thus a valuable asset for the automatic welding of internal seams of tanks and other vessels.

Developments in carbon dioxide shrouded arc welding were to be seen on a number of stands. Two new Philips units were displayed by Research and Control Instruments Ltd. The mobile equipment type ES 3003 has its own built-in power source, using a 400 A constant voltage (selenium) rectifier and dynamic reactor. Power is taken at 440 V 3-phase (30 A per phase). A new version of the Philips automatic carbon dioxide welding equipment was also shown with a fully adjustable welding head. It has its own closed-circuit water-cooling system and its own carriage. A continuous coil of small diameter wire is used; during welding, the wire is fed by a solenoid-operated pressure roll and is automatically straightened by an adjustable arrangement of rollers. Wire speed is continuously variable between 6 and 54 ft/min (1·83 and 16·5 m/min).

The Lincoln Electric Co Ltd exhibited their new Sprite CO_2 fine-wire welding unit. This is especially suited to the requirements of light gauge metal components, and is said to be simple to operate and up to 50 per cent faster than older methods of manual welding. The Lincoln FW1 hand-welding gun used with the equipment will continuously weld sheet sizes down to 20 S W G (0·914 mm) in all positions, even where poor fit-up is experienced. The unit is capable of driving wires of $\frac{1}{32}$ in (0·78 mm) and $\frac{3}{64}$ in (1·2 mm) in diameter, the wire speed being variable between 130 and 300 in/min (330 to 762 cm/min). The welding range is 60 to 200 A.

The Actarc semi-automatic carbon dioxide welding unit shown by Arc Manufacturing Co Ltd consists of a light-weight well-balanced hand gun, a wire drive and control unit, and a 600 A constant voltage power source. The featherweight pistol-grip hand gun is said to be very easy to use, its water circuit keeping it cool at currents of up to 600 A. The wire drive unit can be mounted on top of the rectifier or slung from a rail or gantry. It consists of a mechanically governed wire feed motor, dual-drive feed rolls, post-purge gas and water timer solenoids, safety pressure switch for water, and control relays.

Crompton Parkinson Ltd showed for the first time argon-shrouded stud welding on light alloys. Porosity and atmospheric contamination of the weld are minimised by bringing argon gas through a brass shroud into the weld zone and retaining it there. A valve attachment at the base eliminates gas wastage by releasing the argon flow only when the hand tool is in position.



400 motor vehicle wheels an hour are produced by this Sciaky automatic spot welding machine

A new machine for vertical welding of plates from $\frac{1}{2}$ in (1·27 cm) thickness upwards was shown by Rockweld Ltd. Known as the Vertomat, it makes use of two water-cooled shoes boxing the weld metal between the plates being welded. A carbon dioxide shrouded arc is employed. High welding speeds are obtained in a single pass—up to about four times faster than that of manual welding. The equipment comprises vertical rails on which is mounted a welding head carriage incorporating the control for vertical movement, wire feed, and an oscillating mechanism (the last being necessary for welding plate thicknesses of $1\frac{1}{4}$ in (3·18 cm) and above). Pressure switches and relays ensure that welding is stopped in the event of gas or water failure.

Weld Inspection

A feature on the stand of Solus-Schall Ltd was a section devoted to methods of automatic weld testing. For longitudinal weld testing, four miniature 70° angle probes are used in parallel, with an ultrasonic flaw detector and flaw alarm unit. Water is the coupling medium and the equipment detects longitudinal weld defects such as slag, cracks, lack of penetration, lack of side fusion, porosity, and also transverse cracks. The equipment is suitable for use with plate thicknesses between $\frac{1}{4}$ and $\frac{3}{8}$ in. (6·35 and 9·5 mm). It is possible to adapt the system for use on spirally welded seams, including the reverse spiral welds which arise when two sections of strip are joined together.

Watson and Sons (Electro-Medical) Ltd are now marketing equipment for Zeroradiography. This can produce high-quality X-ray images of welds in less than 30 seconds after exposure. Examination of the plate is best carried out in the viewer provided, which cuts out ambient light and illuminates the plate from a low angle. The viewer has a 35 mm precision camera built into it for use when a permanent record is required.

New equipment and processes

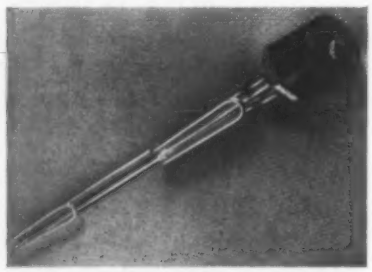
Two-Element Immersion Heater

A new and improved version of the 'Twimerser' dual-purpose immersion heater has recently been introduced by A E I-Gala.

Functionally it is the same as the earlier models in that it incorporates two elements of different lengths and different loadings, giving the most economical conditions for heating either a smaller quantity or a full tank of water.

The principal improvement in the new 'Twimerser'—known as Model EM—is that it has only one moving part, whereas previously there were four. The changeover from small quantity (sink) heating to full tank (bath) heating is easily made merely by rotating the top cover, and a further convenience is that the 'sink' and 'bath' indications are repeated at three positions so that they are readily visible irrespective of the angle of the 'Twimerser' when it is finally tightened up in the tank. A magnifying 'window' is also incorporated in the top cover so that thermostat and temperature settings can be easily checked.

The loadings of the two elements are 2 kW and 3 kW respectively, and their lengths are 10 and 36 inches (25 and 91 cm). The longer element can if necessary be re-formed on site to any length down to 23 inches (58 cm). Voltage ranges are 200 to 220 and 230 to 250 V a c. (*A E I-Gala Ltd*, 33 Grosvenor Place, London, SW1.)



The 'Twimerser' dual-purpose immersion heater

Angle Safety Unit for the E M I C O N Numerical Control System

A recent development for use with the E M I computer-controlled machine tool system is the angle safety unit—a safety device which can be incorporated in all those E M I-controlled contour cutting machines which include the facility for compensating for a cutter of different size from that for which the programme was made. It derives its control information from the built-in computer that controls the machine, but since it continually has access to the computer output before it is actually used to control the machine, it is able to predict a fault and stop the machine before the machine follows the mistake.

In the E M I system of machine tool control, co-ordinates of suitable points on the contour to be cut are considered by the programmer in groups of three consecutive points. These groups are known as spans; they do not overlap but they do have common end points.

The equipment interpolates a smooth parabola passing through each group of three points as calculated by the programmer. Many contours are smooth throughout, and thus consecutive parabolic spans are arranged by the programmer to blend tangentially into one another.

If however one of the three points forming a parabolic span does not lie on the smooth contour, the junction between this and the preceding span becomes a sharp corner whose contained angle depends on the degree of offset of the point which is not on the contour.

In this new equipment there is a rotary device called a resolver, the angle of whose shaft is continually indicating the angle of the surface of the contour at the point which is being cut. It does this by sampling the commanded displacement of each axis over a very short length of time. Samples are continuously being taken of how much the machine has just been told to move and of how much it is going to be told to move. If therefore the angle of the surface changes suddenly by more than a pre-set amount because of an offset point, the advance information sample immediately detects the transient and trips the safety circuits.

When the programmer wishes to insert a sharp corner by design, he must also insert a corner code in the programme at that point, and this is used by the equipment to inhibit the safety unit. (*E M I Electronics Ltd*, Hayes, Middlesex.)

G E C Contactors

Announcing a new range of a c and d c vertical lift contactors for industrial, commercial and domestic use, the Installation Equipment Group of the G E C states that on test the new product's performance was unaffected after 5 million operations.

Contactors are being used much more widely to control special tariff heating and lighting loads, as well as for many other forms of circuit control. Special features of the new G E C models include almost silent operation—through the use of rubber mountings between contactor and case; easily replaceable silver-faced contacts with two breaks on each pole; a moulded arc box to give good arc-resisting and non-tracking properties. Side-mounted auxiliary switches can be fitted, and so can neutral links and control fuses. Paralleling links are available.

The contactor cases are of pressed steel, with ample knockout entries. For easy installation and maintenance, there is generous wiring space within the case; only a screwdriver is needed for dismantling.

The range covers models from 20 A to 200 A a c and 40 A d c, with a choice of operating coil voltages from 100 to 600 V. It is stated that they exceed the requirements of B.S. 775 : 1956. (*The General Electric Co Ltd of England*, Installation Equipment Group, Four Ashes, Wolverhampton, Staffs.)

Lipping Machine for the Woodworking Industry

A new single-edge progressive lipping machine, specially designed for the medium-sized factory, is now in production by Philips. It incorporates the Philips DF 2000 1 kW high frequency heating generator.

A particular feature is the facility for quick alteration of the settings, and the unit can easily be moved to a new position in the shop, so that the maximum advantages of flow production can be obtained, even on short runs.

The simplicity of line and operation of the new Philips lipping machine is shown in this photograph

Production speeds are 11 to 29 feet (3·4 to 8·8 m) a minute depending on the thickness of the material, and the type of adhesive. Panels from 6 to 36 inches (15 to 91 cm) wide overall and 0·5 to 1·5 inches (12·7 to 38 mm) thick can be accommodated, with lippings 0·25 to 1·5 inches (6·3 to 38 mm) in thickness.

The whole unit consists of three sections —loading, drive and sealing, and off-loading. Each section is a separate, very rigid bench, 36 inches (91 cm) high, constructed of top quality hardwood, and with working surfaces finished in Formica.

The drive and sealing section carries the combined pressure and drive unit and the electrode assembly, with the h f generator placed on the floor immediately beneath it.

Lippings and panels are kept flush by a spring-loaded pressure roller which covers the joint of panel and lipping, and is mounted on the same carriage as the upper electrode assembly. To adjust this carriage for width and thickness it is only necessary to release two very accessible locknuts, move the assembly on its guides and relock the nuts. The lower electrode is fixed.

The heavy-duty electrodes are self-positioning and run easily over the joint to be sealed.

Cleaning is easy, as the appropriate sections of the working surface are quickly removable.

Pressure and drive are provided by a JKO variable drive unit which has both forward and reverse directions. This enables both edges of a batch of panels to be lipped simply by returning them through the machine, with a substantial saving in handling and time.

The Philips DF 2000 1 kW h f generator operates only when material is actually within the sealing area and requires no manual switching. It has mains and heating current on/off controls, with pilot lamps to indicate operating readiness, and requires no operating skill on the part of the attendant. (*Philips Electrical Ltd*, Century House, Shaftesbury Avenue, London, WC2.)

The Crabtree ceiling switch with a nylon switch actuator which can be operated from a wide angle

New Ceiling Switch by Crabtree

Designated Type AC, this surface-mounting ceiling switch is offered in 5 A one- and two-way, and 15 A double-pole ratings. It is suitable for use with the British Standard circular iron box or it may be mounted directly on to the ceiling, when a back-plate of incombustible material is available when it is necessary to comply with I E E Regulation 207 (G).

The long-life rotary mechanism is so designed that normal usage cannot place the switch in an inoperative position, nor can it leave the silver-faced contacts in partial engagement. The switch actuator is of nylon—in this application a virtually unbreakable material—and can be operated through a wide angle by a tough Terylene cord. Where necessary, replacement of the pull cord can be made at the union without removing the attractively-shaped damp- and dust-resistant cover which completely conceals the switch-fixing screws.

While its quiet action makes the new Crabtree ceiling switch particularly suitable for controlling bedroom lights or in any situation where silence is desirable, it may also be employed with confidence on commercial fluorescent lighting circuits, since the 5 and 15 A patterns are capable of controlling six and eighteen 80 W fluorescent lamps respectively. (*J. A. Crabtree & Co Ltd*, Lincoln Works, Walsall, Staffs.)

'Dreamland' 3-Heat Electric Blanket

This new electric blanket, which won the premier award at the Electrical Engineers (A S E E) Exhibition last March as the most outstanding domestic appliance exhibit, is now generally released.

The makers state that it is Britain's first two-colour electric blanket; one side of the flameproofed fleeced rayon outer cover is coral pink and the other side sky blue. The edges are finished with a contrasting silver-grey binding.

Designed primarily as an under-blanket to be placed on top of the mattress, it incorporates several novel features designed for maximum safety in use.

The flexible heating element is waterproofed and enclosed between layers of a specially developed cellular material which is completely incombustible. These are in turn enclosed between the outer covers, and the whole assembly stitch-welded by a special di-electric heating process into one inseparable unit in such a way that each run of the element is held firmly in an accurately aligned channel.

This method of construction, which is exclusive to the firm and has been patented by them in most countries of the world, ensures that however the blanket is folded or creased, no two runs of the element can ever come sufficiently close together to cause overheating. The blanket complies with the relevant British Standard Specification.

A 5-position illuminated switch is incorporated (3 heating and 2 'off' positions); loadings are 80 W for the single bed size, 60 by 30 inches (152 by 46 cm), and 130 W for the double bed size, 60 by 48 inches (152 by 122 cm), and models are available for 200 to 220 V and 230 to 250 V mains.

A single-heat version is also made, fitted with a neon-illuminated switch; sizes and loadings are the same as the 3-heat model.

It is significant that firms in eight countries overseas are negotiating for licences to manufacture locally, and the British patentees would welcome any other enquiries on these lines. (*Easipower Appliances Ltd*, 30 High Street, Southampton, Hants.)

Pye Induction Generator

This new induction generator is a 12 kW unit, available in either air- or water-cooled versions, and designed for continuous operation.

The availability of medium and high kVA in the work coil permits the heating of a wide range of ferrous and non-ferrous loads. The output power can be varied by means of a stepped control, while accurate repetition work can be carried out by reason of the inclusion of an automatic resetting process timer.

The safety devices include water pressure switches, overload relays, and safety switches behind movable panels. Provision is made for remote output indication and on/off control; coloured indicator lamps show which circuits are switched on. Because of the simplicity of operation, unskilled labour can be employed, thereby enabling production costs to be reduced. (*Pye Ltd, Process Heating Division*, 82 James Street,Cambridge.)

Low-priced Earth Leakage Circuit-Breaker

The Chilton Type C earth leakage circuit-breaker represents a new advance in the design of voltage-operated earth leakage protection units. Essentially, it is designed to provide a dependable, robust and highly sensitive unit at very competitive prices.

Its leading features include: facility for wiring for mains incoming or outgoing from top or bottom terminals; tamper-proof mechanism in dust-protected enclosure; extra large, bright yellow 'push to test' bar instead of the usual small test button; clear and concise test instructions for the user prominently and permanently displayed on the front of the moulded case; modern and attractive appearance.

The type C earth leakage circuit-breaker is the latest of several types of similar 'trips' or circuit-breakers manufactured by Chilton for many years for world-wide use, and it now supersedes the earlier type ELT/A 'trip'. The type C, which complies with B S 842 : 1939, is a double-pole earth leakage circuit-breaker; it is not a circuit-breaker with an earth leakage attachment.

Two versions are available, with current ratings of 60 A and 100 A respectively, and suitable for single-phase supplies of 200 to 250 V to earth. Both versions are housed in the same size of casing, which is moulded in phenolic urea and finished in cream and black. (*Chilton Electric Products Ltd*, Hungerford, Berkshire).

The Chilton earth-leakage circuit-breaker, a prominent feature of which is the 'push-to-test' bar

Electric Water Heaters Instead of Fighter Aircraft

To cope with the steadily increasing demand, both in the U K and in many countries overseas, for their Sadia electric water heaters, the Aidas Electric Co Ltd have recently established another large factory at Salisbury, the famous cathedral city in the West of England.

This is the latest development in the history of a now well-known company which started in 1932, when its late founder began to make the first British Sadia models in a small factory at Willesden, in the north-west of London. His pioneering work in the field of electric water heating led to the establishment in 1938 of the Sadia works at Northolt, in Middlesex, with a production area of over 100 000 square feet (9 290 m^2), now augmented by a further 60 000 square feet (5 570 m^2) in the new Salisbury factory.

Two points about the factory itself are of interest. First is the fact that it was built in 1943 for the wartime production of the famous Spitfire fighter aircraft, and it was still in use for the manufacture of aircraft components until last year. Its adaptation to the production of water heaters involved a number of alterations and an extensive re-wiring and re-decoration programme.

Rapid Build-up of Production

The other point of interest is that Salisbury is predominantly an agricultural and rural area, and few of the present employees (who are mainly women and all recruited locally) have had any previous industrial experience. They have, however, responded readily to training in the light assembly work involved.

The initial output of the new factory is 250 water heaters a week, but this will build up steadily to 1 350 a week when peak production is reached.

The principal product is a new version of the Sadia 'Twoplus' electric water heater—a self-contained 2¼ gallon (10 l) model designed for mounting above the sink or wash basin.

A New Type of Outer Casing

One of the outstanding features of this new heater is the use of 'Stelvetite' for the fabrication of the outer casing instead of the previous cellulose or stove-enamelled sheet steel. 'Stelvetite' is a comparatively recent introduction and consists of a plastic coating intimately bonded to sheet steel; the plastic coating is practically everlasting and will not chip, crack or part from the base material either during fabrication or in use. The 'Stelvetite' chosen for the Sadia 'Twoplus' model has a white plastic coating with a slightly grained surface, giving the finished heater a very attractive appearance.

Basically, the heater can be regarded as an assembly of three main components: the outer cylinder fabricated from 'Stelvetite'; a tinned copper inner cylinder, and the base assembly carrying the water inlet and outlet pipes, the heater element and the thermostat.

The plastic-coated steel and the copper are delivered to the works in sheets 10 feet (305 cm) square which are cut into panels of the required dimensions by an electrically-operated guillotine.

Three presses working at pressures of 80, 50 and 30 tons (81 300, 50 800 and 30 500 kg) respectively, stamp out the top and bottom plates from the 'Stelvetite' sheet. A hand-operated roller and versatile brake press are employed to shape the cylinder for the outer casing.

Double Testing

The copper sheets are rolled into cylinders to which the domes and bases are seam welded. Pressure tests determine the continuity of the welds and eliminate any mis-shapen units prior to the tinning process, in which the containers are dipped in a vat of pure molten tin. After tinning, further hydraulic testing takes place at more than double the pressure the containers are likely to encounter during their working life.

The third major component—the base assembly—is built up from a brass base plate. This is pre-drilled to accommodate a copper thermostat tube, the heater element tube, and the baffle dome to the cold water inlet, all of which are secured by expansion joints before the assembly goes through the tinning bath. Subsequently, chromium-plated outlet and inlet extensions and an independently tinned flow-tube are added. At this stage the heater is ready for assembly.

Twin chromium-plated bands, which considerably enhance the finish of the 'Twoplus', are fitted and the top and bottom plates screwed in position.

Inside the casing a heat-retaining blanket of resin-bonded fibreglass encloses the water container and is held in place by bakelite support fittings. A cork block at the top of the container and a glass-fibre covering pad effectively complete the insulation, and the heater's zinc-coated back plate is then attached.

The heating element and thermostat are added on the final assembly bench, and the complete heater is wired and tested to 1 500 V before being cartoned for despatch.

Aidas Electric Ltd also produce immersion heaters and thermostats in the new factory, and the production will be steadily built up to 5 500 immersion heaters and 10 500 thermostats a week.

Sadia Overseas

The Sadia electric water heater has become well established in many overseas markets, and one recent installation is at the internationally famous Raffles Hotel in Singapore. In modernising this hotel, the hot water facilities are being brought up to date by the use of Sadia floor-mounted pressure-type electric water heaters of 80 and 100 gallon (364 and 455 l) capacity. These models, which are of course thermostatically controlled, are made with one-, two- or three-element plates, each loaded to 6 kW.

Book Reviews

Progress in Dielectrics (Vol 3). *By J. B. Birks and J. Hart.* 10 × 6½ *in* (254 × 165 *mm*). *Pp* 292 + *vii. Index. Illustrated.* (*London: Heywood & Co Ltd*, 1961.) Price 63s.

Surveys of progress in any subject are always useful, but it is doubtful whether there is any real need for them to be published as a series of annual volumes. The amount of work in a given field can hardly be critically reviewed on a yearly basis, because of the short time scale involved.

The present volume contains six papers: Dielectric Waveguides and Aerials; Theories of Dielectric Polarisation and Relaxation; Dielectric Properties of Water; Mechanisms of Dielectric Absorption in Solids; Recent Developments in Cable Insulation in the United States; and Theory of Dielectric Breakdown in Solids. All the papers have merit, although the one on cable insulation seems rather out of place. They represent however an expensive way of acquiring the knowledge, since they could have been more cheaply published in scientific journals, which workers in the field of dielectrics would surely not have overlooked.

Each paper contains an extensive list of references, but in very many cases the value of these is reduced by the omission of the title of the paper referred to. This is a most serious defect in any bibliographical information, because it prevents one from deciding whether the particular source should be studied in full for a given aspect of the subject.

J.H.J.

The Testing of Electrical Machines. *By Laurence H. A. Carr.* 8¾ × 5¾ *in* (222 × 146 *mm*). *Pp* 299. *Index. Illustrated.* (*London: Macdonald & Co*, 1960.) Price 50s.

To the man who has electrical engineering 'in his blood', the test room of a manufacturing company is always a place of absorbing interest. It is a place where both men and machines are tested; where a trained man, ever on the alert for the unexpected, will never cease learning; and where, in the process, he will 'prove' his own value to his colleagues responsible for the machines handed over to him, as well as the ability of the machines to meet their calculated performances.

Such a man will revel in this book, and those who aspire to become test engineers will find in it just the technical and practical guidance needed for duties on the test floor; guidance, moreover, provided by an engineer who knew the business from A to Z, who was a good theoretician and solidly practical.

The book deals only with rotating machines and it is confined to standard classes of such plant. Moreover, the examples given throughout the text relate to large machines, although this in no way limits the application of the work.

The first chapter is entitled 'General considerations regarding testing' and it is remarked upon here because it is so unmistakably the 'signature' of the practical engineer and the keynote to the whole book. The machines dealt with in the next eleven chapters are the d c machine, the induction motor, the synchronous machine, the synchronous induction motor, the synchronous motor, the a c generator, the synchronous condenser, and the turbo-generator. In these chapters sufficient theory is given to enable the reader to understand and appreciate what underlies the tests and how the test results are to be interpreted and evaluated. All the various tests required are enumerated and described and illustrated by graphs, vector diagrams and tables where appropriate.

The remaining four chapters deal with testing equipment, testing of work in progress, balancing, and precautions to be taken during erection for test. All these bear additional testimony to the hand of an engineer who has 'done the job'.

The book has been very well planned and written, and in preparing it the author has rendered a considerable service to the electrical engineering profession, particularly to the younger members in training or in junior posts. To engineers and trainees in factories, in consulting practice, and in colleges the book is, beyond question, of the utmost value and it cannot be recommended too highly.

It is sad to have to remind readers of the author's decease and this review is offered as a small tribute to his constant service to others, from one who knew him well.

S. AUSTEN STIGANT

A First Course in Electromechanics. *By Hugh H. Skilling.* 9 × 6 *in* (229 × 152 *mm*). *Pp* 340 + *xii. Index. Illustrated.* (*London: John Wiley & Sons*, 1960.) Price 36s net.

This new undergraduate book on the principles of electrical machines is a most welcome and refreshing addition to the literature of electrical engineering. In preparing the text the author has sought out the most useful principles of electromechanical energy conversion and emphasised the similarities, rather than the differences, among the various electromechanical devices. By adopting this method he has avoided the narrowness of the traditional encyclopaedic treatment usually provided in undergraduate books dealing with electrical machines.

The author is undoubtedly correct in adopting this approach, for the undergraduate student of engineering has no need of an intimate knowledge of the details of the inner working of electrical machines. This latter information is only required by designers and specialists, and this knowledge is better met by means of specialist postgraduate books.

How this broader treatment is rendered possible is seen by considering the contents of the sixteen chapters, illustrated by 212 line diagrams, which cover successively electromechanical principles, mechanical force, energy relations, energy and inductance, the commutator machine, the synchronous machine, the induction motor, the transformer, electromechanical equations, complex impedance and transfer functions, Laplace analysis of signals, Laplace impedance and transfer functions, types of function and responses, typical devices and electromechanical systems. There are also two appendices on magnetic circuits, units and dimensions.

The author has provided the reader with 33 references for further study and there are also 158 examples at the end of the book, by means of which the student can test his understanding of, and the progress made in, his reading of the subject. There is unfortunately no index; this deficiency should be rectified in the next edition.

The forward-looking treatment gives considerable attention to the dynamic state of electromechanical devices, and in consequence there are only 16 phasor diagrams in the whole book. This is a measure of the new look the subject has received during recent years. The emphasis is on the system in which the machine has to function.

Although this text is written primarily for the use and instruction of undergraduate students of electrical engineering, much of the contents is appropriate to the needs of the student of mechanical engineering. In fact, the use of a text like the present could well help to dispel the dislike which many mechanical students have for their electrical engineering studies.

This book is printed on good quality paper and has a bold type, materially assisting the reader. This particular book, and others of similar outlook, will have repercussions on all future undergraduate courses in electrical engineering. It is well recommended and well worth possessing.

P. F. SOPER

Modern Mathematics for the Engineer. *By Edwin F. Beckenbach and Magnus R. Hestenes.* 9¼ × 6¼ *in* (235 × 159 *mm*). *Pp* 456 + *xviii. Illustrated. Index.* (*London: McGraw-Hill*, 1961.) Price 74s.

This book is a further volume in the Engineering Extension Series published for the University of California and the text derives its substance from the 1958-59 course of lectures given at the University on modern advanced mathematics applicable to science and engineering. The first series with the above title was published in 1956 and was reviewed in our issue of August, 1957.

The present volume has been planned in a manner similar to that of its predecessor, being divided into three parts which are: mathematical methods, statistical and scheduling studies, and physical phenomena. The topics discussed in these are intended to be complementary to those contained in the first series and they are as follows.

In Part 1: from delta functions to distributions (A. Erdélyi), operational methods for separable differential equations (B. Friedman), integral transforms (J. W. Miles), semigroup methods in the theory of partial differential equations (R. S. Phillips), and asymptotic formulas and series (J. B. Rosser).

In Part 2: chance processes and fluctuations (W. Feller), information theory (D. Blackwell), the mathematical theory of control processes (R. Bellman), formulating and solving linear programmes (G. B. Dantzig), and the mathematical theory of inventory processes (S. Karlin).

In Part 3: Monte Carlo calculations in problems of mathematical physics (S. M. Ulam), difference equations and functional equations in transmission-line theory (R. Redheffer), characteristic-value problems in hydrodynamic and hydromagnetic theory (S. Chandraskhar), applications of the theory of partial differential equations to problems of fluid mechanics (P. R. Garabedian), the numerical solution of elliptic and parabolic partial differential equations (D. Young), and circle, sphere, symmetrisation, and some classical physical problems (G. Pólya).

In summary, Part 1 presents advanced mathematical methods involving operators in Hilbert space, distributions, transforms, semigroups, and asymptotic approximations, and shows their many applications to physical and engineering problems. Part 2 covers such topics as random-walk problems, queueing problems, information theory, control processes, linear programming, and inventory processes. Part 3 includes Monte Carlo methods, matrix methods, and machine computation, employing the techniques previously described.

Numerous examples and exercises are given throughout the book which, bearing in mind its advanced character, is intended for engineers, scientists and mathematicians as well as for use in colleges.

We welcome this volume as cordially as we did the first series and recommend it with enthusiasm.

S. AUSTEN STIGANT

Alternating Current Circuits (Fourth Edition). *By Russell M. Kerchner and George F. Corcoran.* $9\frac{1}{4} \times 6$ *in* (235×152 *mm*). *Pp* $602 + x$. *Illustrated. Index.* (*London: John Wiley & Sons*, 1960.) Price 70s.

It is now nine years since the last edition of this undergraduate book on 'alternating current circuits' was prepared. Since that time, teaching developments in presenting the principles and practice of electrical circuit analysis have encouraged the authors to include in this fourth edition new material on topography, duality and the pole-zero method of circuit analysis. In addition to these items, the approach to the network concept has been revised so as to provide a deeper understanding of network analysis.

The text has been prepared in such a way as to provide a textbook on alternating current circuits that is suitable for the needs of undergraduate students. The treatment given to the subject assumes that the undergraduate reader has a good working knowledge of the differential and integral calculus. Although the text presents the subject matter in a thoroughgoing manner and is far from superficial, the analytical work is not overburdened by non-essential mathematics. Probably, for a first reading, many of the topics and more sophisticated sections might well be omitted, so that a general idea of the work of circuit analysis is obtained. Those more advanced topics would be covered during the second reading and provide deeper understanding of the subject which must be fully understood by all electrical engineers.

The fourteen chapters, illustrated by 411 line diagrams and 30 oscillograms, cover successively network concepts, instantaneous and effective quantities, phasor algebra, sinusoidal single-phase circuit analysis, non-sinusoidal waves, coupled circuits, balanced and unbalanced polyphase circuits, transmission line calculations, electric-wave filters, symmetrical components, and transient calculations.

The authors have provided the student with 503 examples by which he can test the growth of his understanding of this important subject.

The treatment given by the authors to this vital part of any student's work in electrical engineering is wide and thorough, and they have introduced many advanced concepts. These concepts are presented in such a way that even the average student can comprehend the ideas and follow the argument. The whole subject is far from superficial, and yet is within the capacity of any undergraduate student.

The book has an attractive layout, is well printed, and the general presentation is one that encourages the student to read. It is well recommended, and will be of benefit to the purchaser throughout his working life.

P. F. SOPER

Mathematics for Telecommunications and Electrical Engineering (Vol. 2). *By D. F. Spooner and W. H. Grinsted.* $7\frac{1}{2} \times 5$ *in* (191×127 *mm*). *Pp xiv* + 514. *Illustrated. Index.* (*London: English Universities Press Ltd*, 1960.) Price 15s net.

This new book is one of the General Technical Series produced under the general editorship of Air-Commodore J. R. Morgan. These technical series of books are intended to meet the needs of those students who aim at acquiring a technician qualification. In this new edition, the authors provide a selection of work in mathematics normally included in most Ordinary National Certificate schemes. The contents will also more than cover the needs of students preparing for the Telecommunications Examination in Mathematics of the City and Guilds of London Institute.

The twelve chapters of the text are illustrated by 171 line diagrams, and in view of the type of reader for whom the book is intended, the authors have wisely followed the pedestrian approach to the subject. In this method, each new topic is immediately followed by a worked example and then numerous exercises to be worked by the student. There are also many complete sets of past examination papers which provide the student with a guide to the standard required to achieve success. In order to assist the lone student, the authors have provided at the end of the book answers to the numerical problems.

One may however wonder whether this type of student really needs to know about many of the topics in the text, and whether his efforts would not be better utilised in other ways.

P. F. SOPER

YEAR BOOKS AND DIRECTORIES

Metal Industry Handbook and Directory, 1961. $8\frac{3}{4} \times 6$ *in* (222×152 *mm*). *Pp* 560. (*London: Iliffe Books Ltd*, 1961.) Price 21s net.

This is a standard work of the non-ferrous metal industry and is now in its 50th year of publication.

The Directory contains up-to-date information on the properties of old and new metals, and there is an extensive summary of British Standards, Aircraft Materials, D T D and Admiralty Specifications. It also contains a Buyers' Guide of metals, metal working machinery and tools, together with lists of manufacturers and stockists.

Electrical Trades Directory. 11×9 *in* (280×229 *mm*). *Pp* 956. (*London: Benn Bros Ltd*, 1961.) Price 70s net.

Over the last few years the *Electrical Journal's* Blue Book has been increasing in thickness and was becoming correspondingly more difficult to handle. The publishers have wisely decided to alter the format of this edition, and the increased page size and three-column entries have resulted in a great improvement.

The entries in all sections have increased; the number of product headings has grown to 2 700, and the electronics section also shows an expansion. The directory contains all the features of previous editions, including the names and addresses of manufacturers, exporters, importers, trade associations and similar bodies connected with the electrical industry.

British Plastics Year Book, 1961. $9\frac{1}{4} \times 6\frac{1}{4}$ *in* (235×159 *mm*). *Pp* 712. (*London: Iliffe Books Ltd*, 1961.) Price 45s net.

The British Plastics Year Book is divided into ten sections. Three are devoted to classified lists of manufacturers and suppliers of materials, finished products, and equipment; a fourth section—new in this edition—lists companies giving basic services from moulding and extruding to welding and metalising. What is claimed to be the world's largest list of trade and proprietary names connected with the industry is given in another section.

The set of tables giving comparative properties of plastics materials has been revised and brought up-to-date, and in the same section are included a revised glossary of technical terms, lists of new companies registered during 1960, and specifications relating to plastics.

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Babcock & Wilcox Ltd	*24*
Belliss & Morcom Ltd	*23*
Berry's Electric Ltd	*26*
Bolton, Thomas, & Sons Ltd	*22*
British Insulated Callender's Cables Ltd	*28*
British Overseas Airways Corporation	*29*
Brush Electrical Engineering Co Ltd	*30*
Bushing Co Ltd, The	*31*
Davidson & Co Ltd	*32*
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Newton Bros (Derby) Ltd	*50*
P & B Engineering Co Ltd, The	*2*
Parsons, C. A., & Co Ltd	*3*
Permali Ltd	*4*
Pirelli-General Cable Works Ltd	*5*
Rawplug Co Ltd, The	*6*
Reyrolle, A., & Co Ltd	*7*
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Simplex Electric Co Ltd	*9*
Smith, Frederick, & Co	*10*
Standard Telephones & Cables Ltd	*11*
Stein, J. G., & Co	*12*
Sterling Varnish Co Ltd, The	*13*
Thomas, Richard & Baldwins Ltd	*14*
Yorkshire Electric Transformer Co Ltd	*15*
Yorkshire Imperial Metals Ltd	*16*
Yorkshire Switchgear & Engineering Co Ltd	*17*

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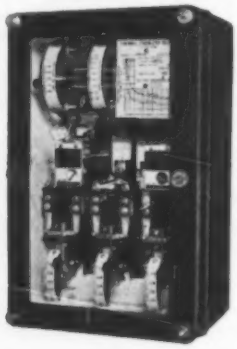

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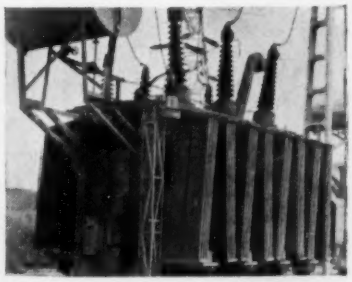
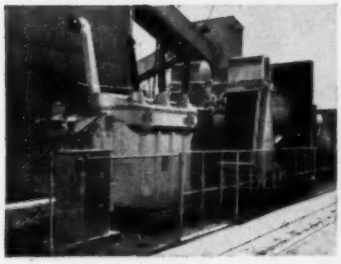
transformer

installations

SPAIN

One of two PARSONS 25 MVA transformers at Andujar sub station Madrid.



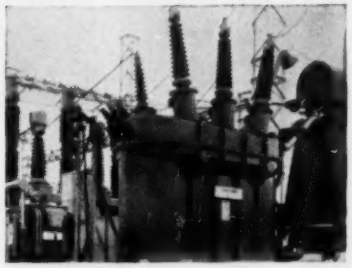


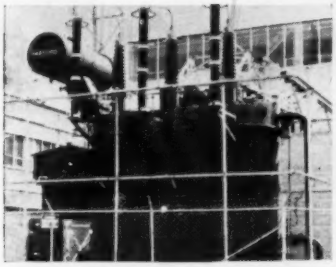
AUSTRALIA

One of three PARSONS 37.5 MVA 11.8/140.8 kV Generator transformers at Bunbury, Western Australia

SOUTH AFRICA

One of two PARSONS 45 MVA 132/88 kV Auto transformers at Coedmore, Natal



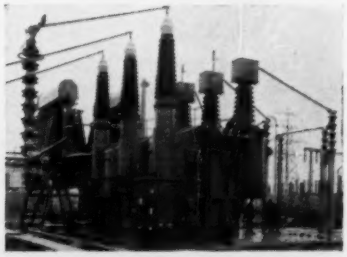


CANADA

One of two PARSONS 75 MVA 14.4/138 kV Generator transformers at Boundary Dam.

ENGLAND

One of two PARSONS 180 MVA 132/275 kV Auto transformers at Keadby.



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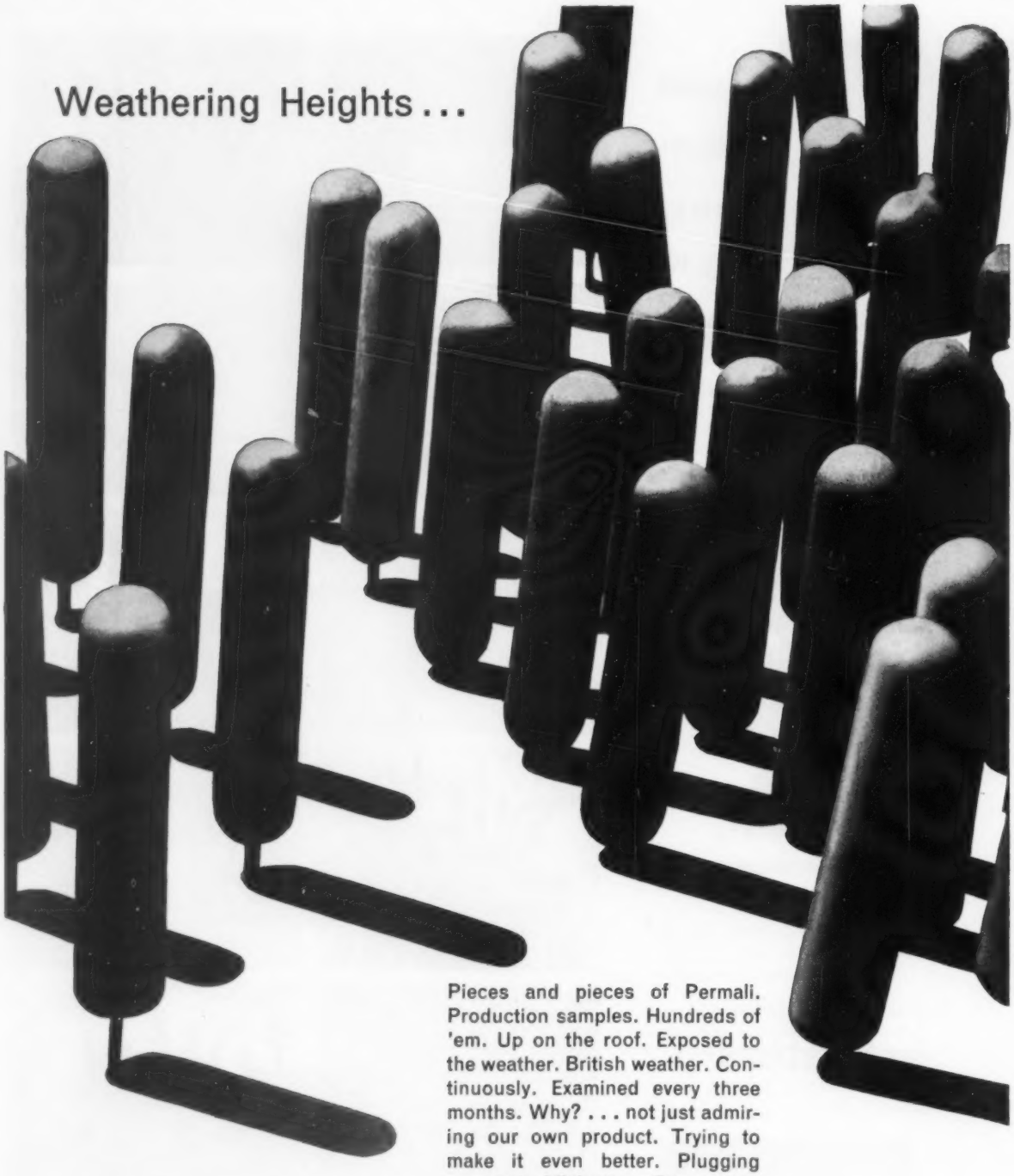

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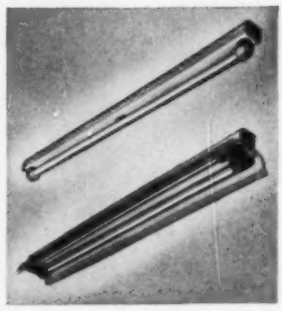

The Simplex ACF (anti-corrosion fluorescent) fitting is protected by a specially patented process that will not rust even in the heaviest corrosive atmospheres.
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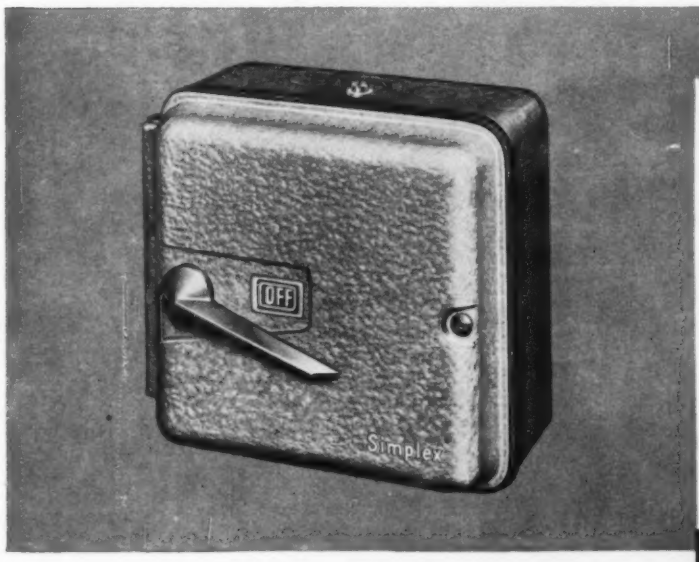

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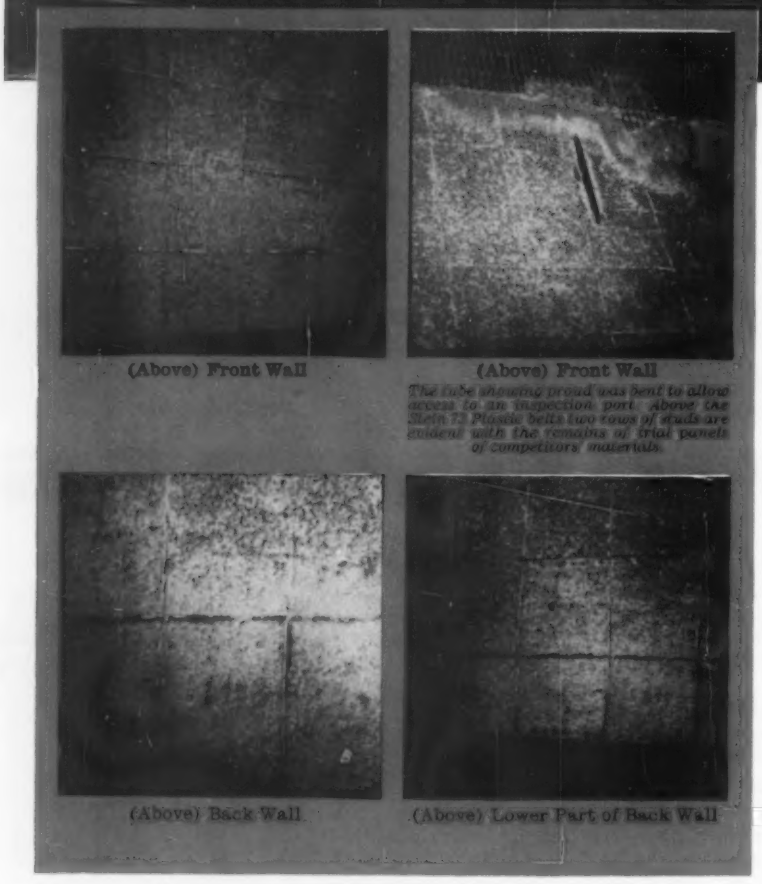

(Above) Front Wall

(Above) Front Wall

The tube showing proud was bent to allow access to an inspection port. Above, the Stein 73 Plastic belts two rows of studs are evident with the remains of trial panels of competitors' materials.

(Above) Back Wall

(Above) Lower Part of Back Wall

The illustrations (left) show the condition of the Stein 73 Plastic Refractory Belts in No. 2 (John Thompson Water Tube Boilers Ltd.) Boiler, Marchwood Power Station (C.E.G.B. Southern Division) after being in almost continuous service for 18¼ months, *which is by far the best result ever achieved.* This boiler has a rating of 550,000 lbs./hr. and the belts, 16 feet high x 32 feet wide, were installed on both the front and rear walls. The hot face temperature of the refractory belts was approximately 1650°C and 1750°C where flame impingement occurred. Actual measurement showed that these temperatures were greatly exceeded at times.

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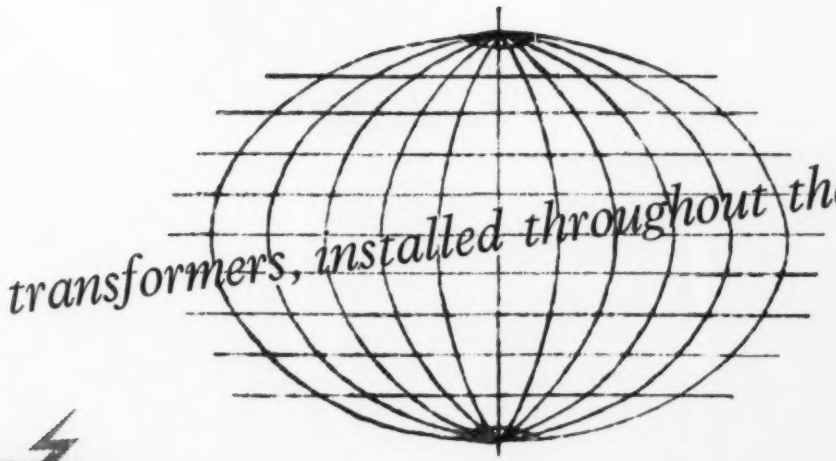

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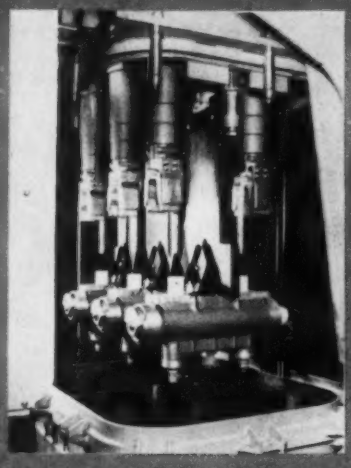

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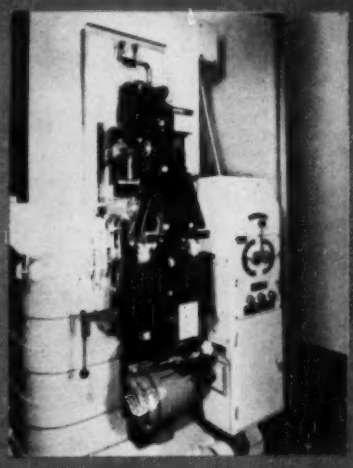

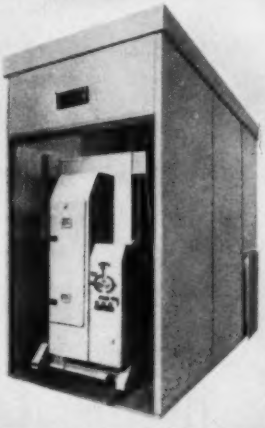

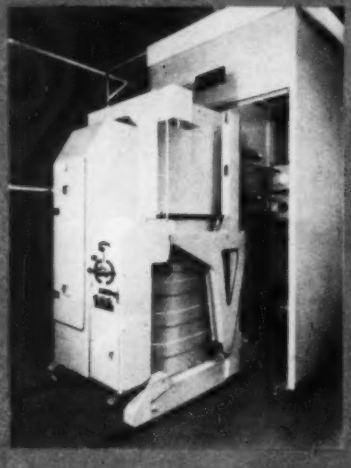

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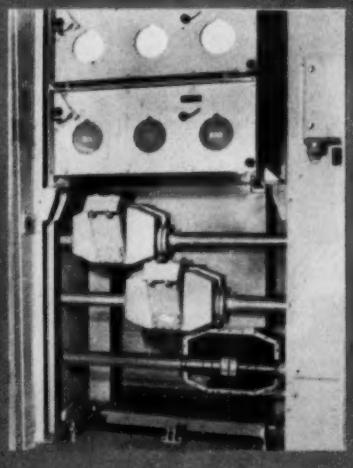

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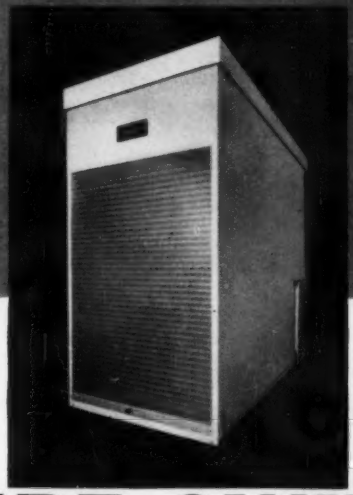

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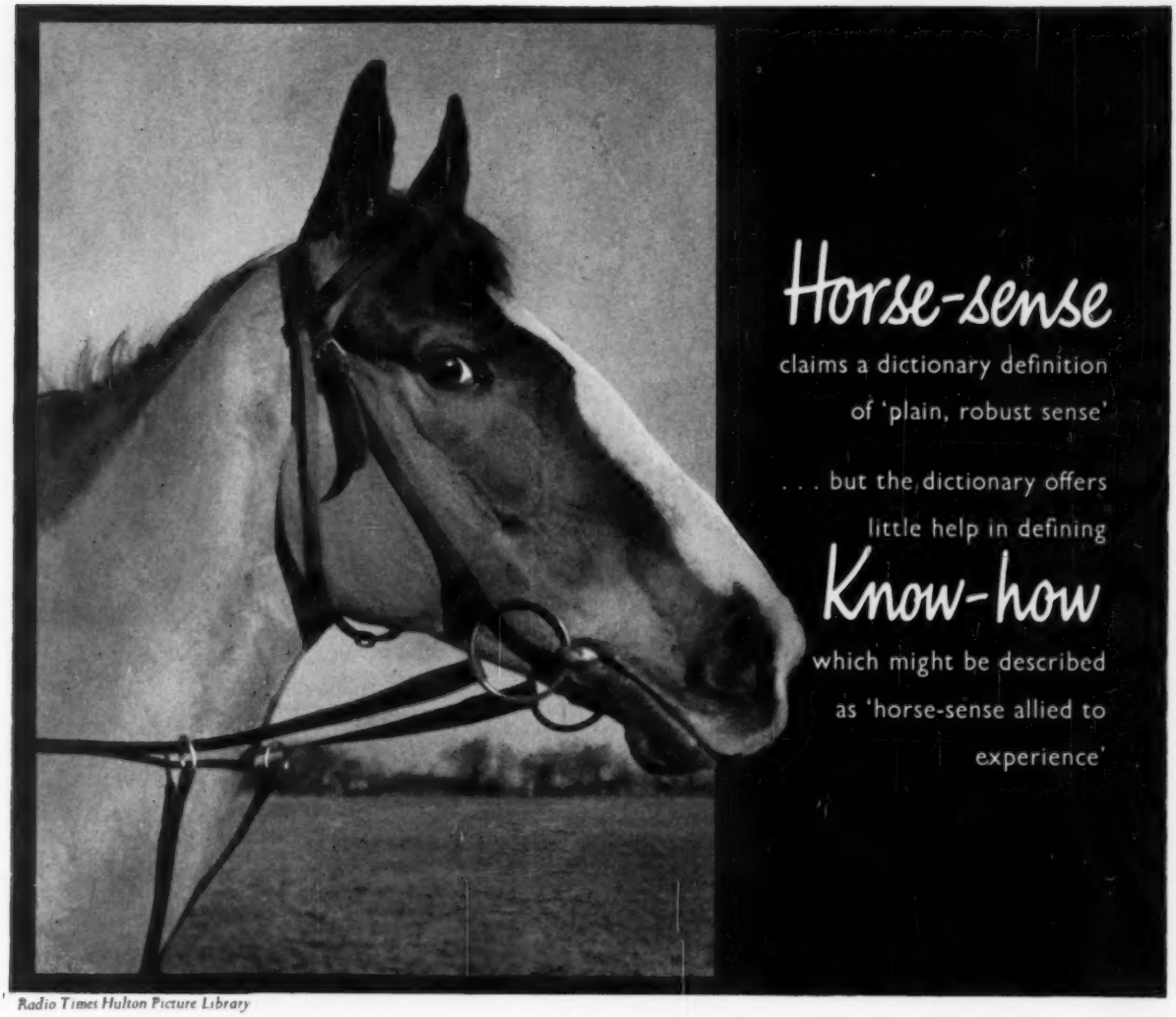

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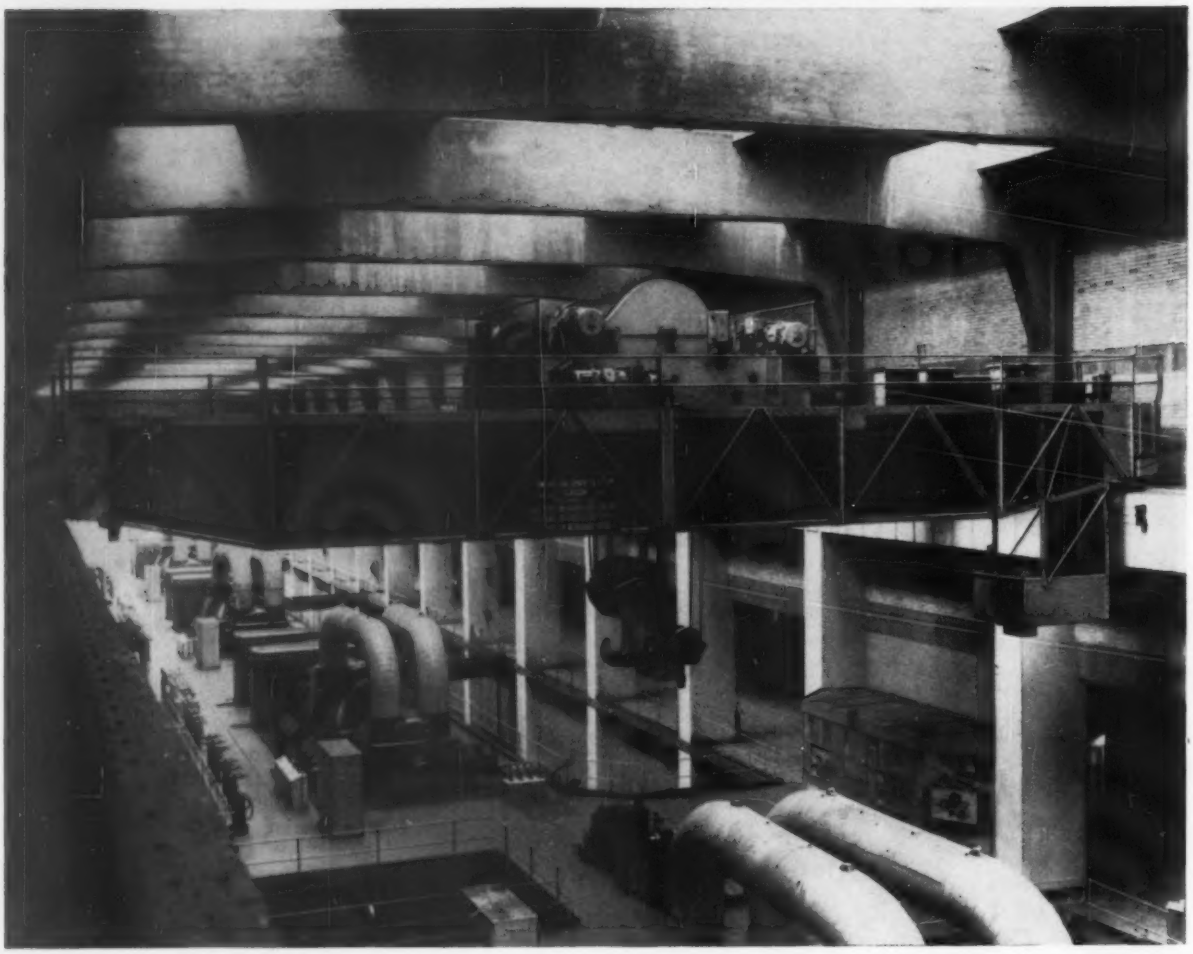

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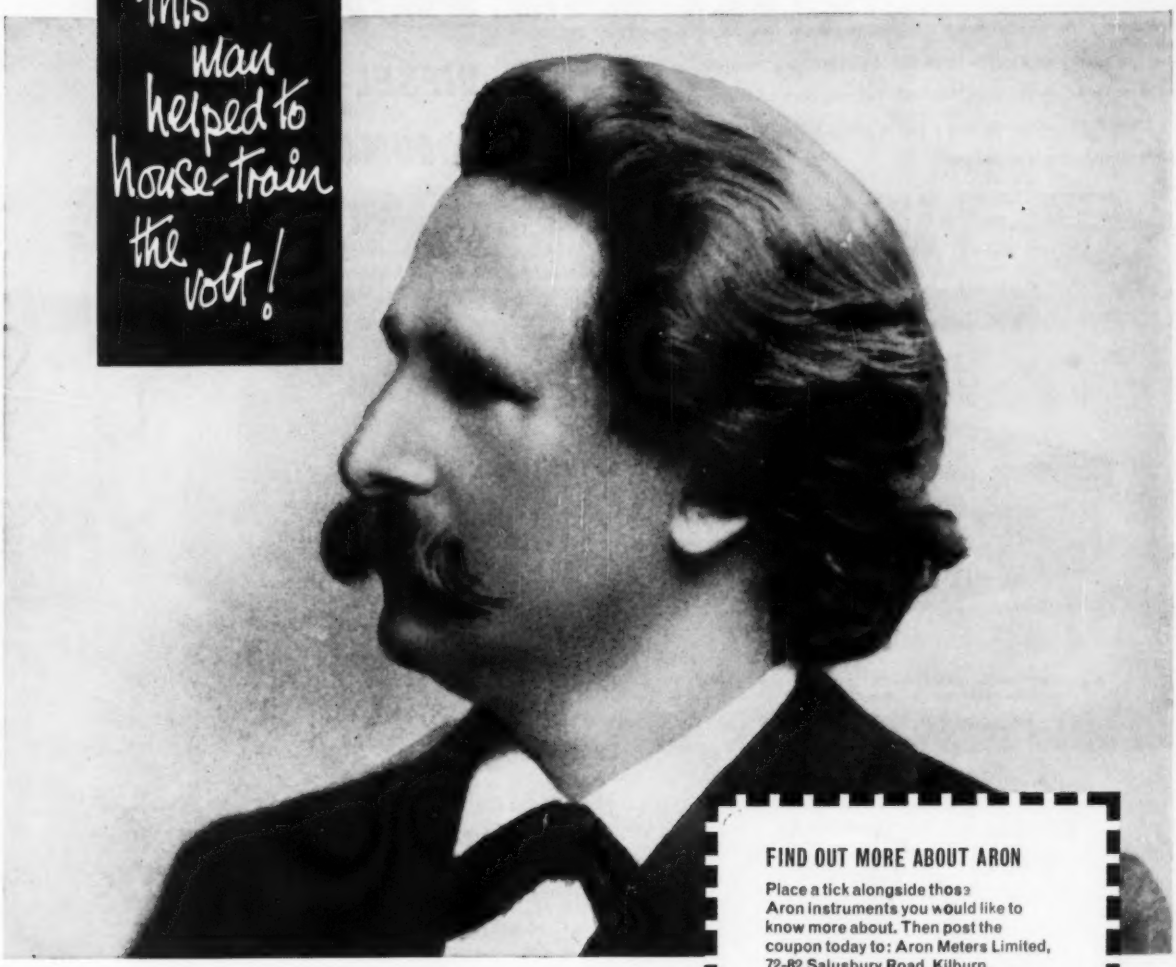

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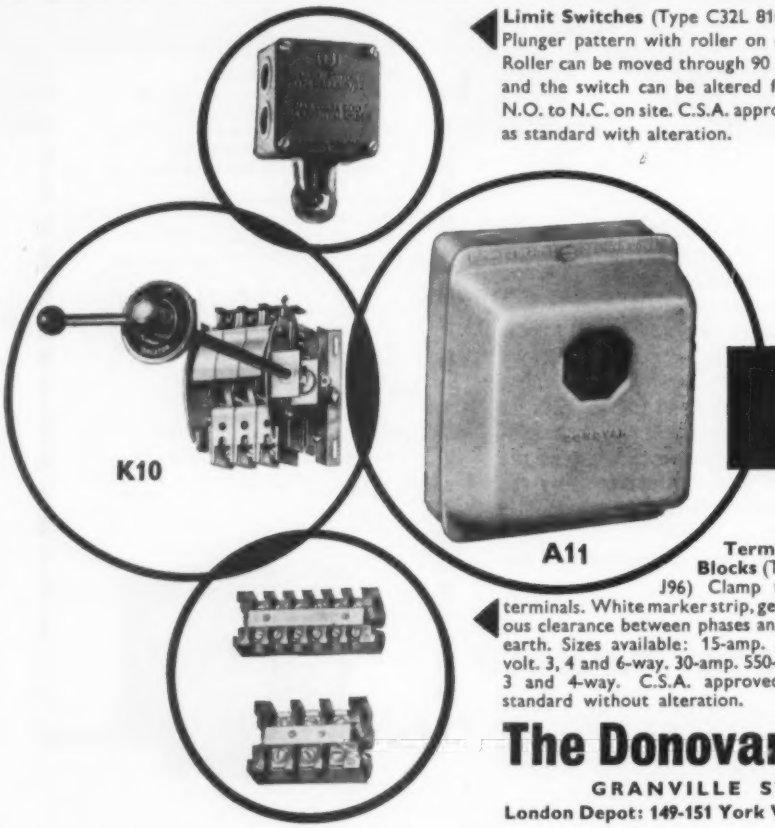
Illustration shows a Type 4 2,000 h.p. "English Electric" diesel-electric locomotive on the Eastern Region of British Railways.

cvs-544

A SELECTION FROM A LARGE RANGE



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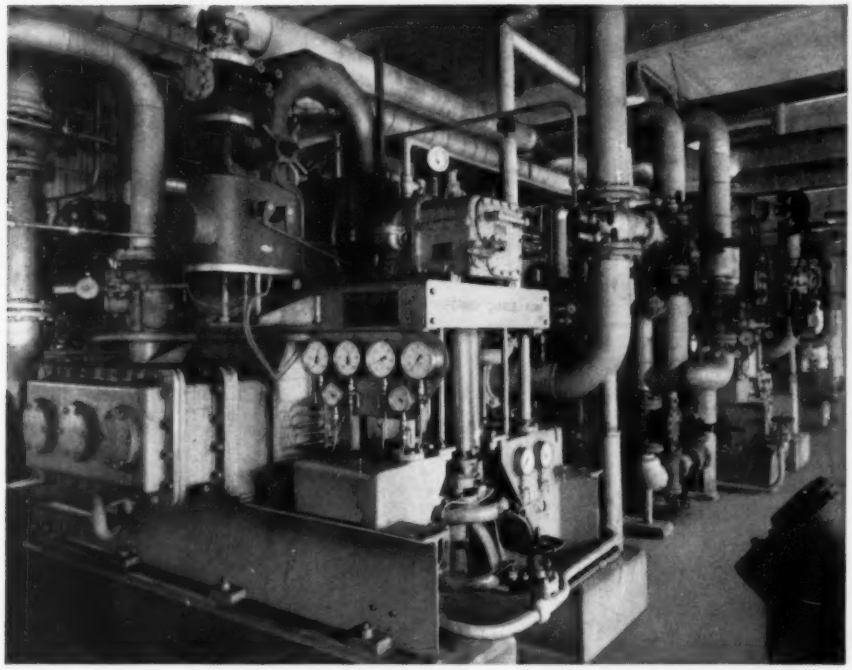

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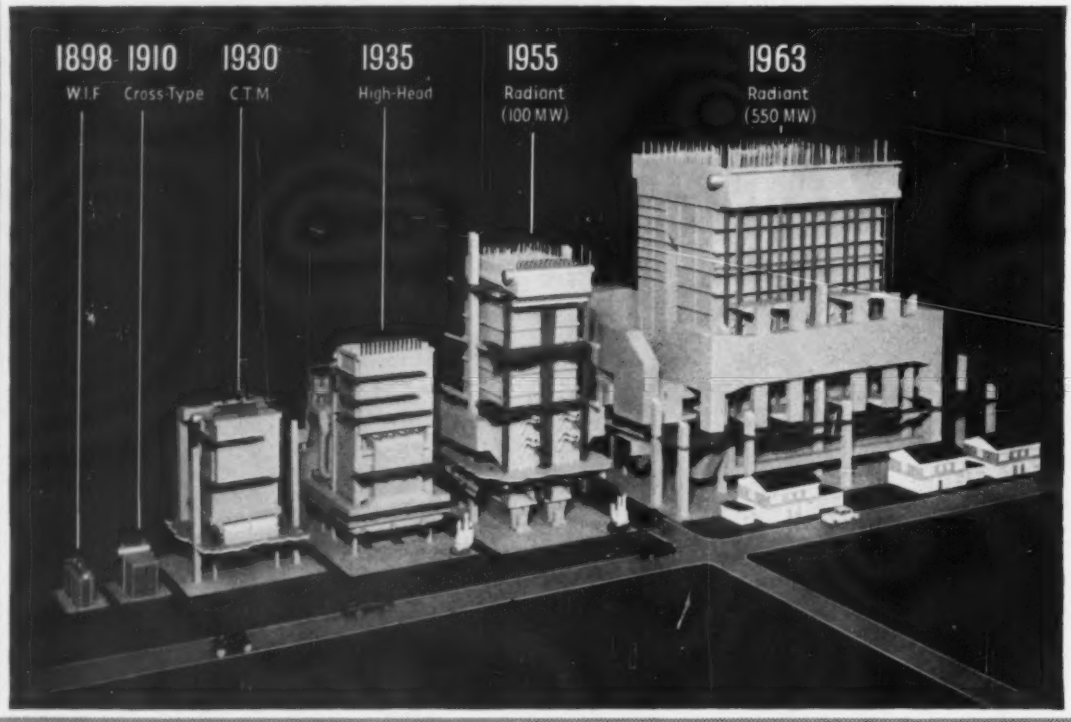
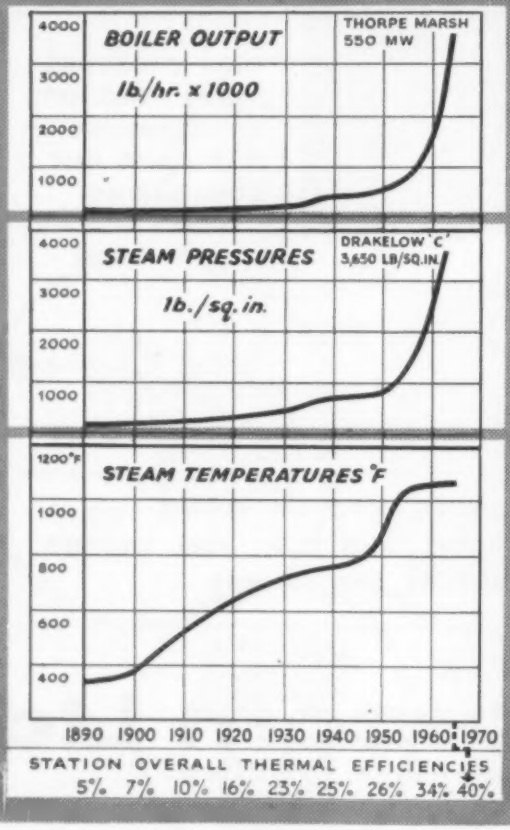
THE MARCH OF STEAM





Progress in power generation, to the present stage of a single boiler to serve a 550 MW set or to operate at supercritical pressure, with central-station thermal efficiencies of the order of 40%, has followed the path of advancing steam technology and engineering, an advance in which, for well over half a century, the BABCOCK organization has been in the lead.

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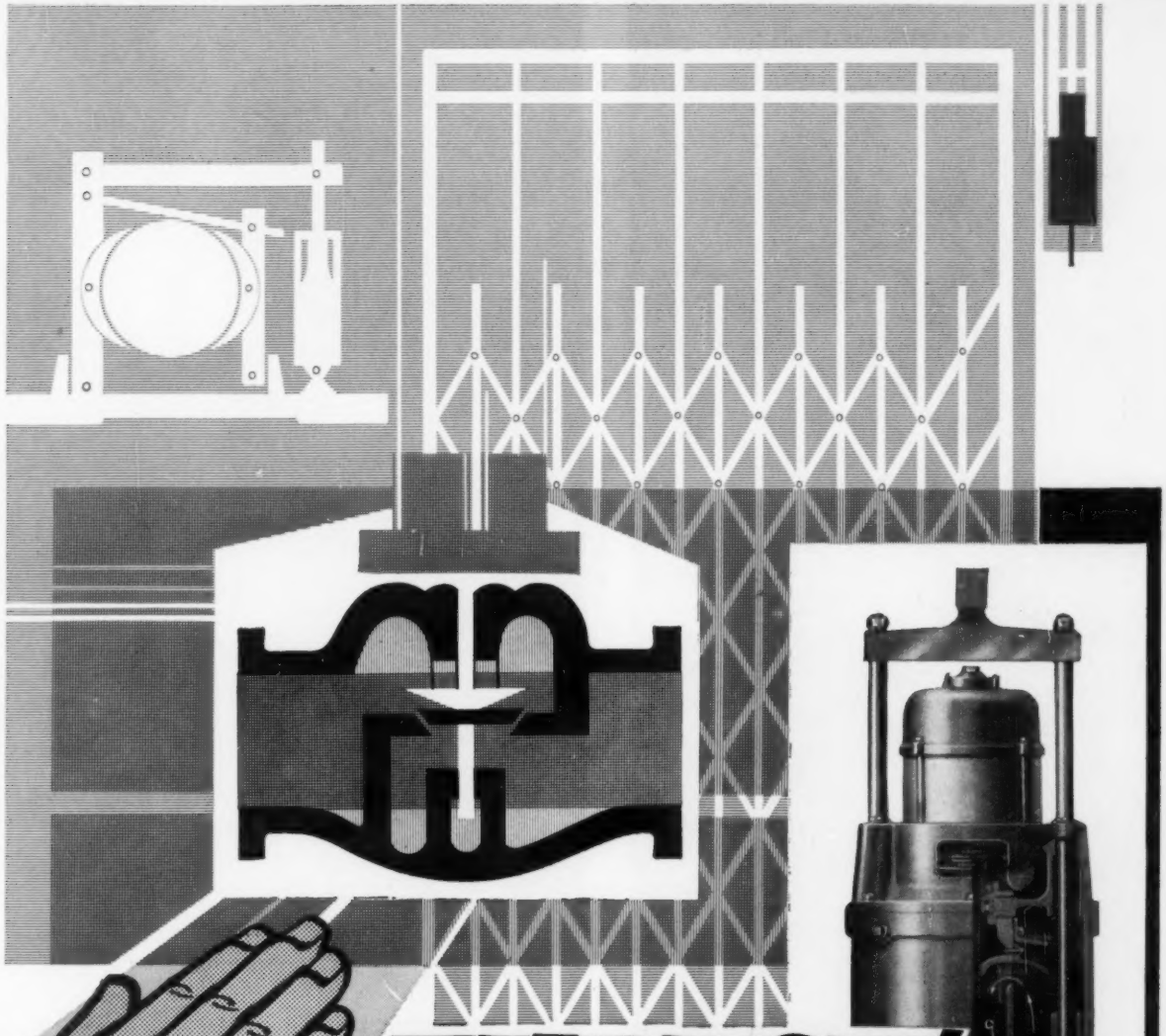

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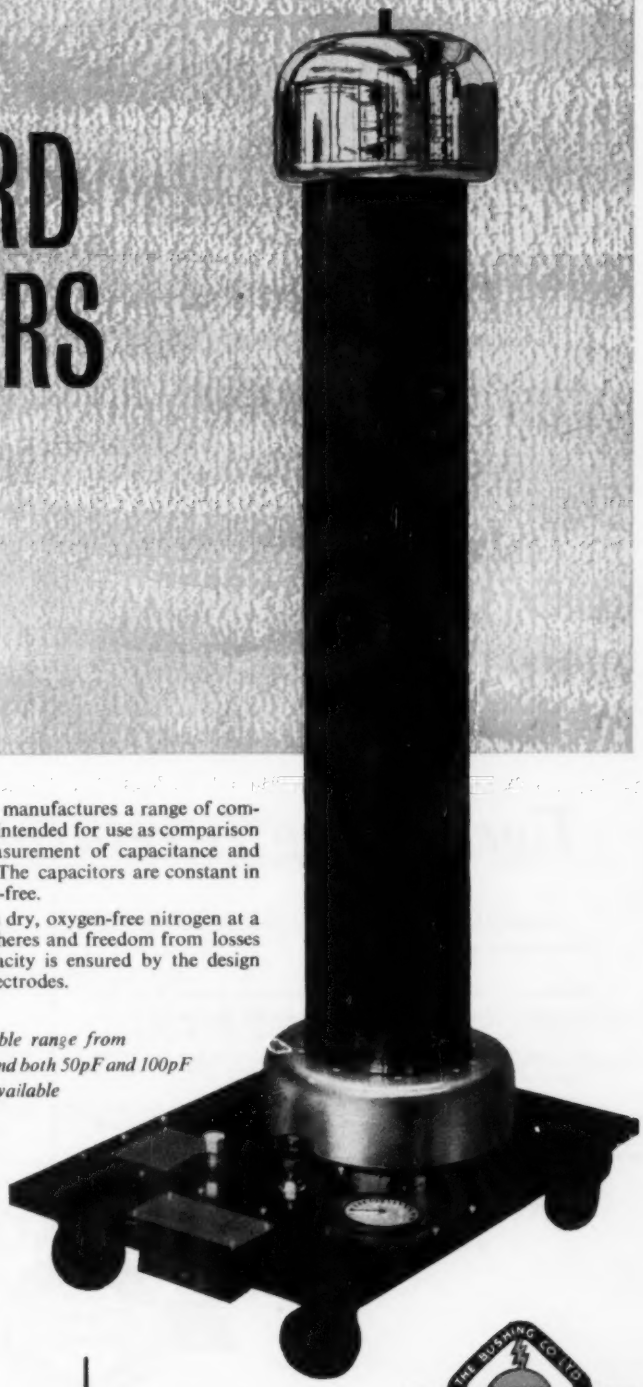

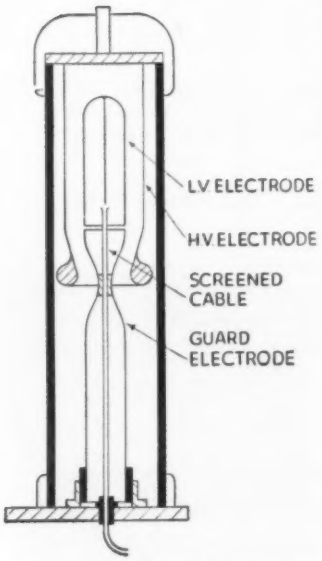

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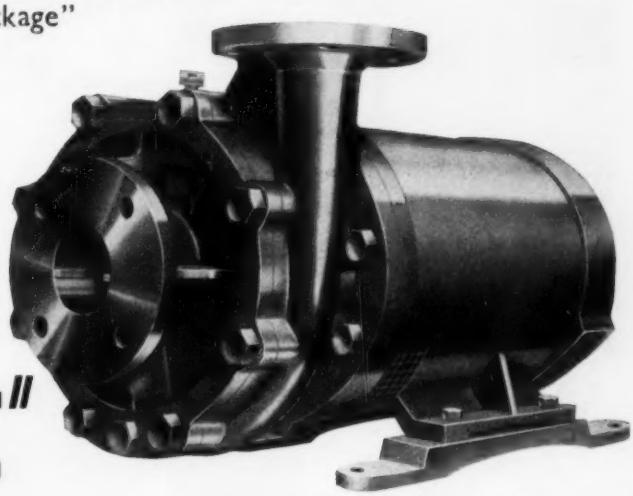

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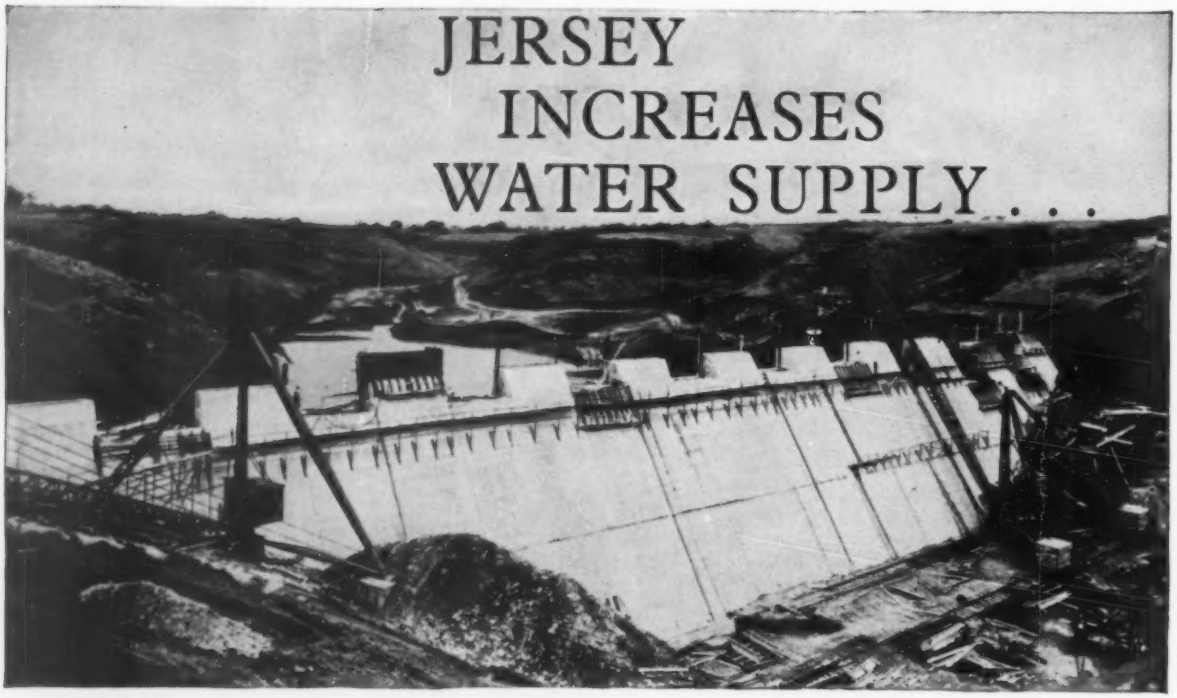

with two new reservoirs

"Erskine Heap" switchgear controls the pumping

Two new reservoirs have been built at Val de La Mare and La Hague and in both cases the pumping is controlled by Erskine Heap Switchboards. The reservoir capacity is 220 million gallons. Pumping rate 150,000 gallons/hr against a 300ft head. The dam is a gravity type, spillover without free board and 50,000 cubic yards of concrete was pumped into position. Total cost of entire project was £600,000.

The Switchboard illustrated on the right is the one manufactured for the Val de la Mare Reservoir Pumping Station, and is similar to that being supplied for La Hague. The multi motor contactor type Switchboard comprises incoming ASTA certified oil circuit breaker unit, the Pump control units each being 160 HP auto transformer starters.

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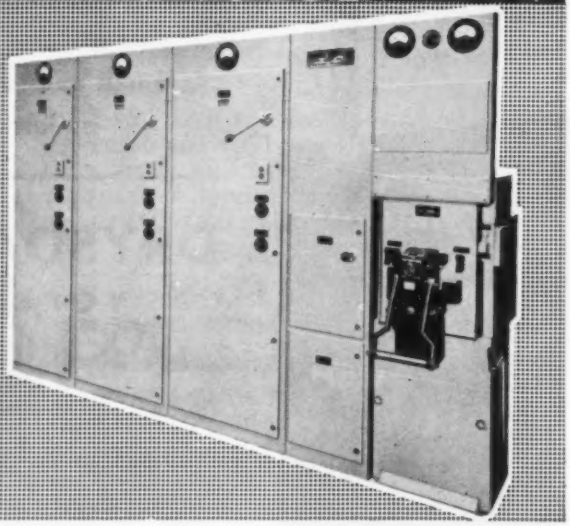

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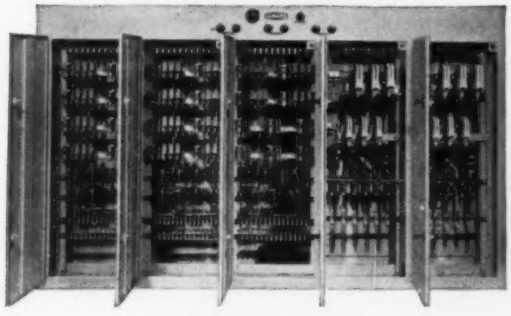

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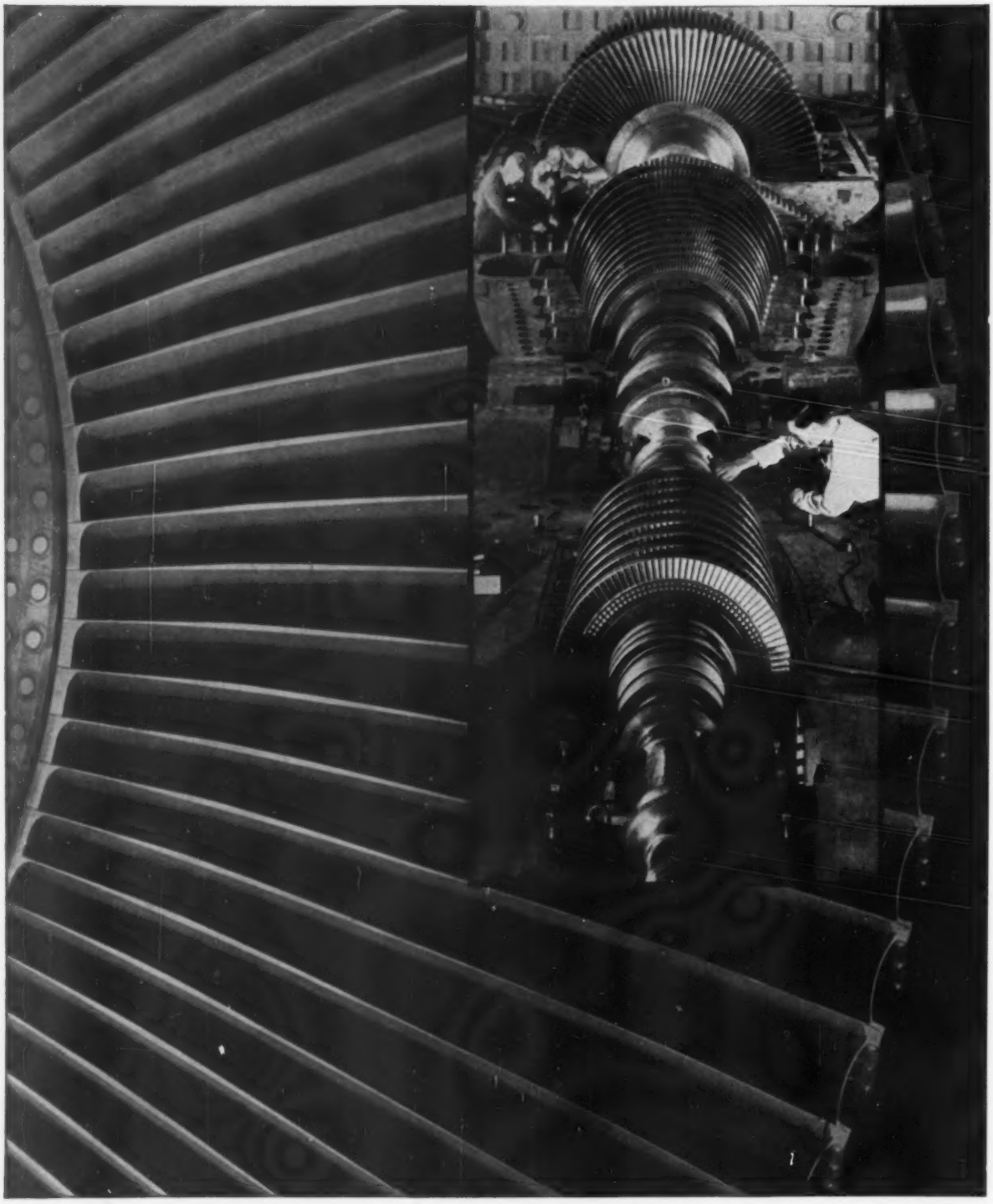

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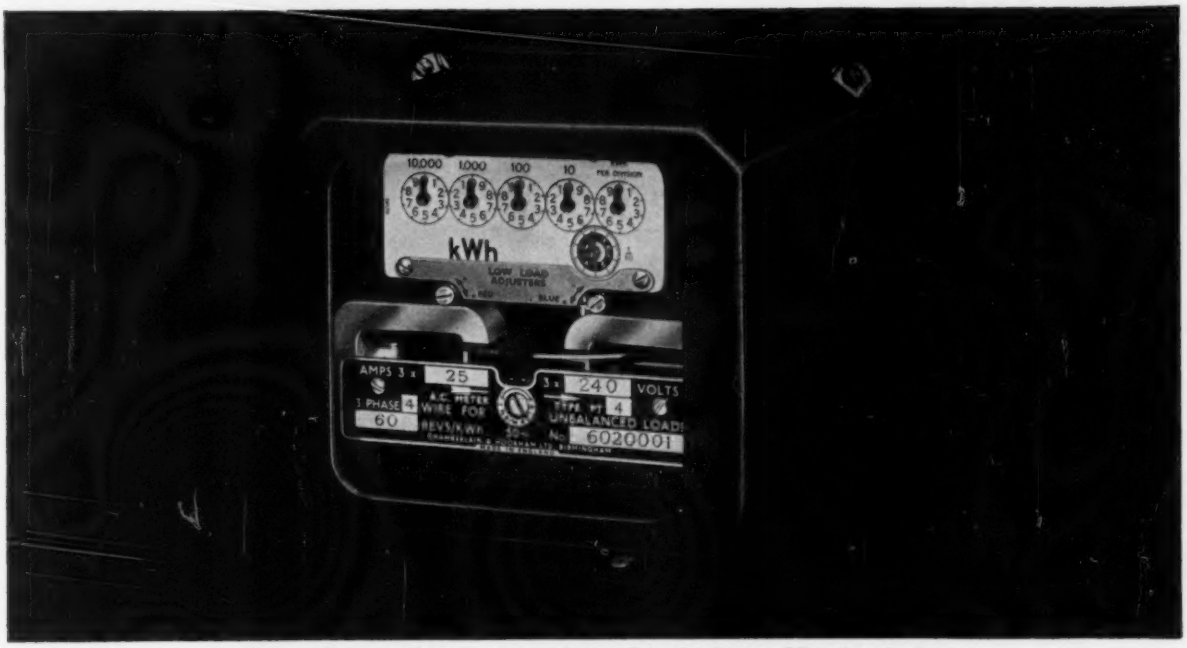

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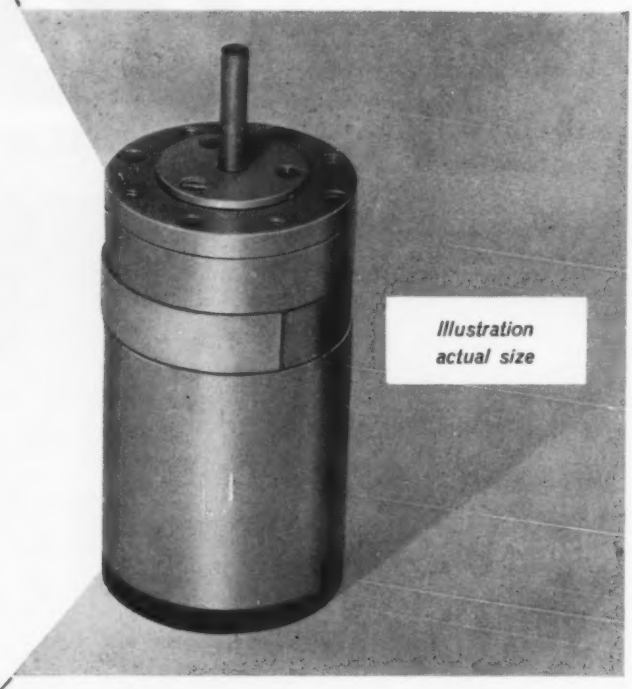

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Designed primarily for Professional Tape Recorders this new EMI Battery Motor (part no. 98170D) is also suitable for Television camera remote control, and for medical and other scientific uses. A high-grade precision-built Motor for long life and exceptional speed regulation over a wide range of load and voltage. A Multi-pole Armature gives low electrical interference, long brush life and high efficiency and a Ball Race bearing is incorporated for handling heavy duty side loads.

Provisional Technical Specification

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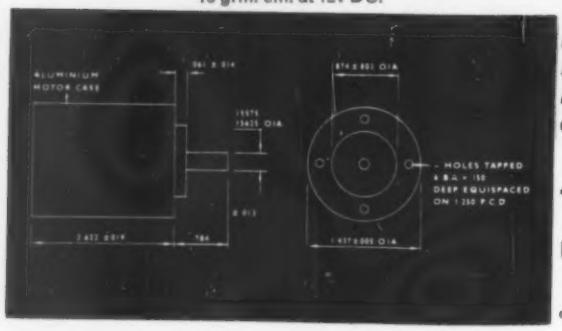
Current:	No load 120mA max. 8-12v At 45 gcms 310mA max. 8-12v
Rotation:	Anticlockwise viewed from spindle end.
Speed and Output:	Max. continuous rating. 2440-2500 r.p.m. at 45 grm. cms. torque at 12v DC +0v 2390 r.p.m. minimum at 45 grm. cms. torque at 8v DC −0v Speed regulation over governed range at constant voltage 0.75 r.p.m. per grm. cm. torque. Speed regulation over governed range at constant torque 12·5 r.p.m. per volt DC Max. No load ungoverned 12v No load governed 8v Minimum torque at governed speed 15 grm. cm. at 12v DC.



EMI also manufacture a wide range of inexpensive battery motors suitable for Domestic Tape Recorders, Gramophones, Fans and a host of other applications where a governed torque of up to 10 gm. cm. at 1600 r.p.m. or 2600 r.p.m. is required.

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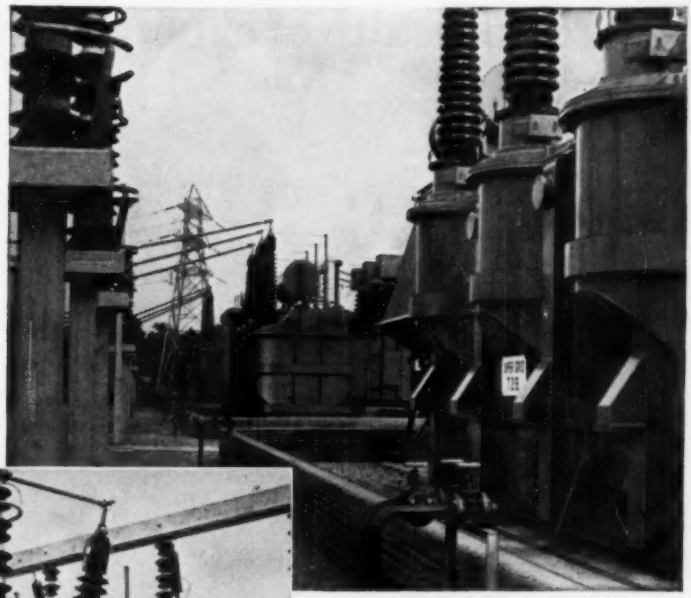

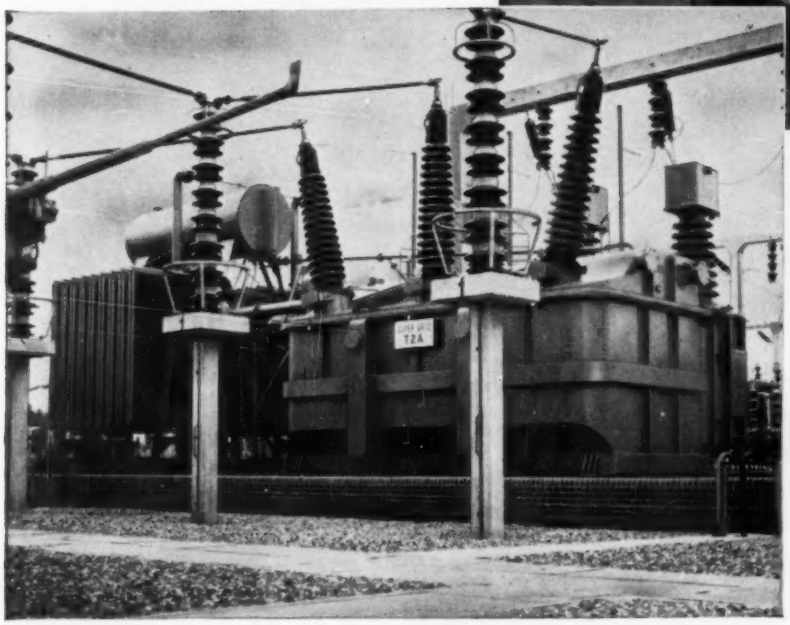

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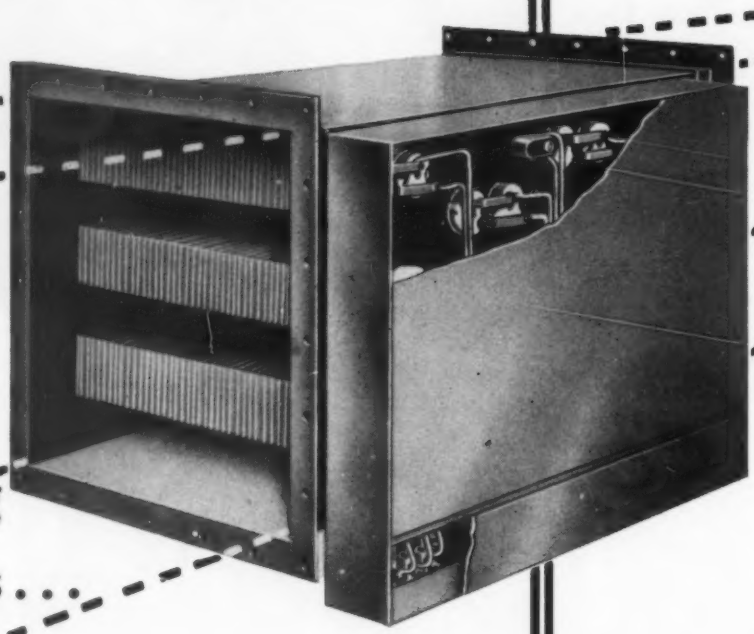

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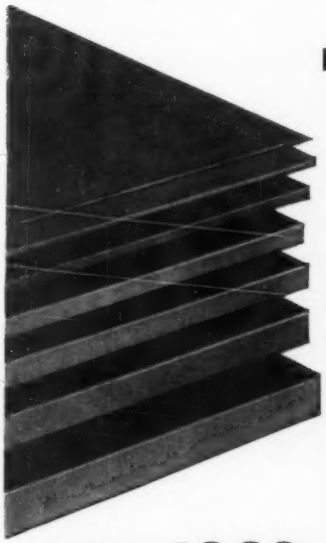

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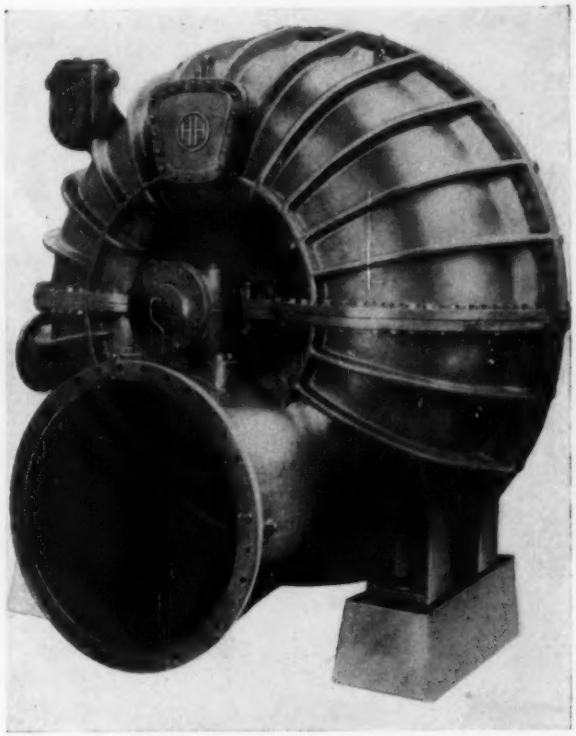

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The Hick Hargreaves self-cleaning enclosed Rotary Water Strainer is proving, in service throughout the world, to be the most effective means of removing floating debris. The strainer comprises a motor-driven wheel, slowly rotating inside a casing, the straining medium which is between the spokes being so designed to prevent the interlacing of fibrous matter. The head loss through the strainer does not exceed 2 feet. The debris is removed from the strainer by a series of jets, and discharged from an internal chamber which is effectively sealed off from the main water space. All water connections are placed in the lower half of the casing and large access doors are provided for routine examination. Installation is extremely simple, no extensive foundation work being necessary. The strainer can be located on either the suction or discharge side of the circulating water pumps.

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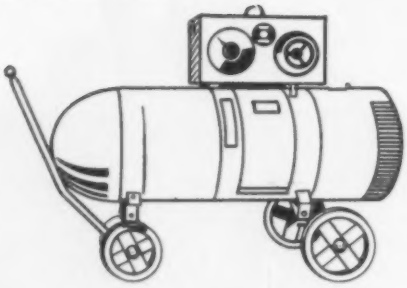

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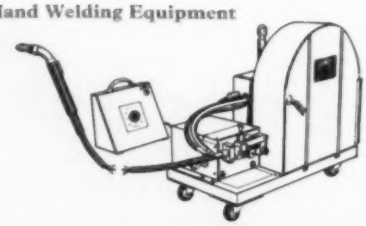

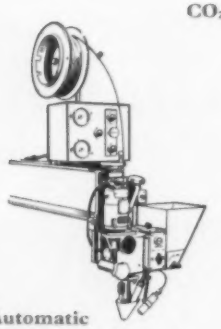

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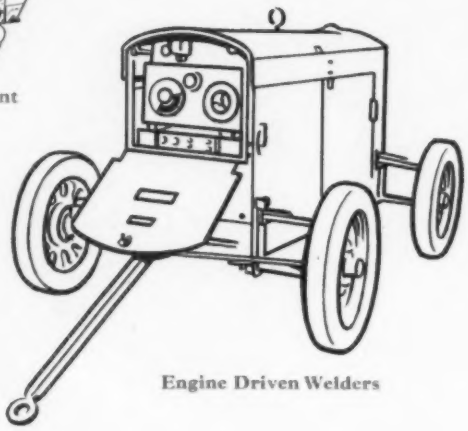

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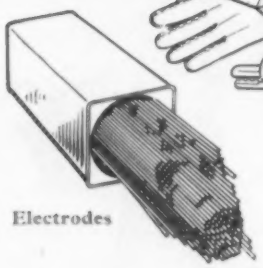
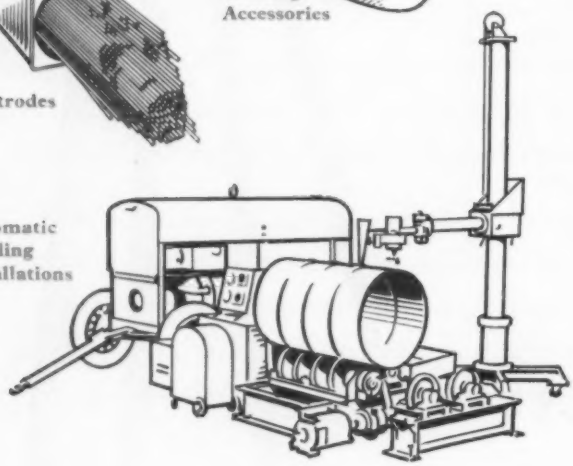


Electrodes



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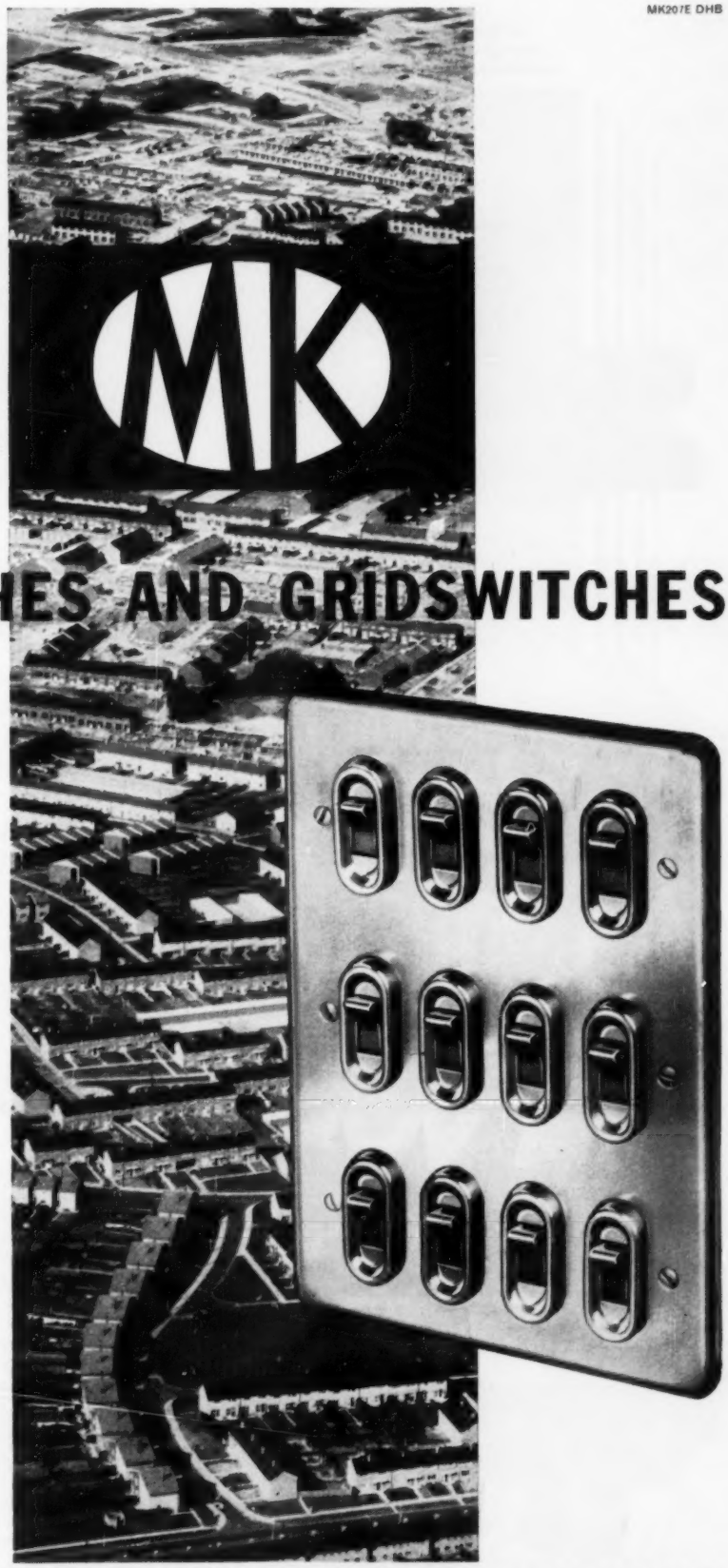

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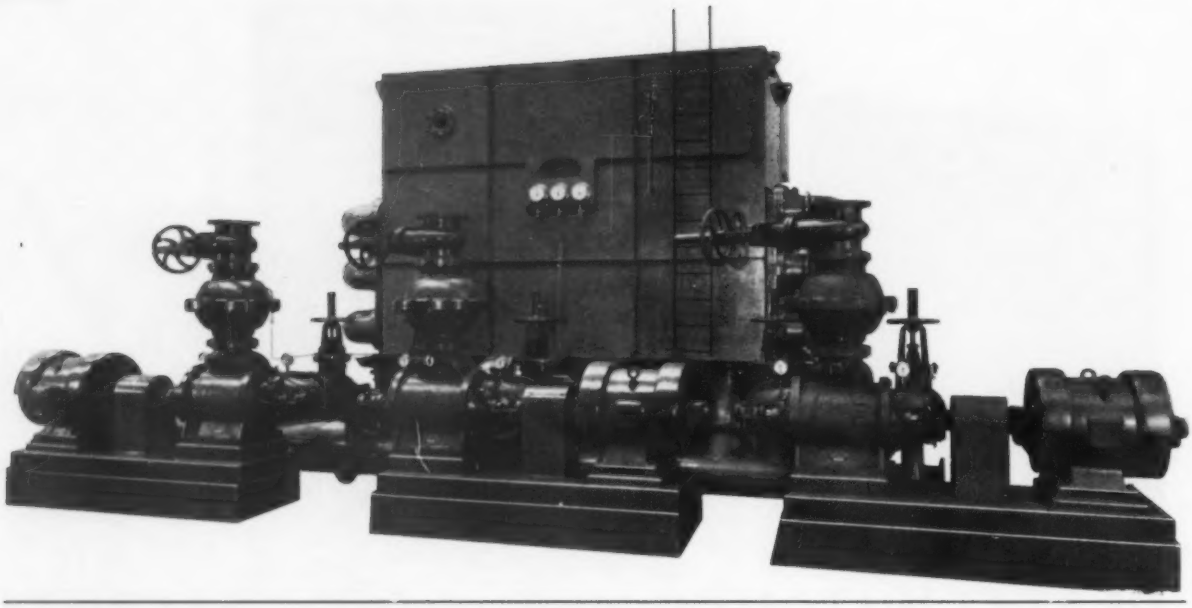

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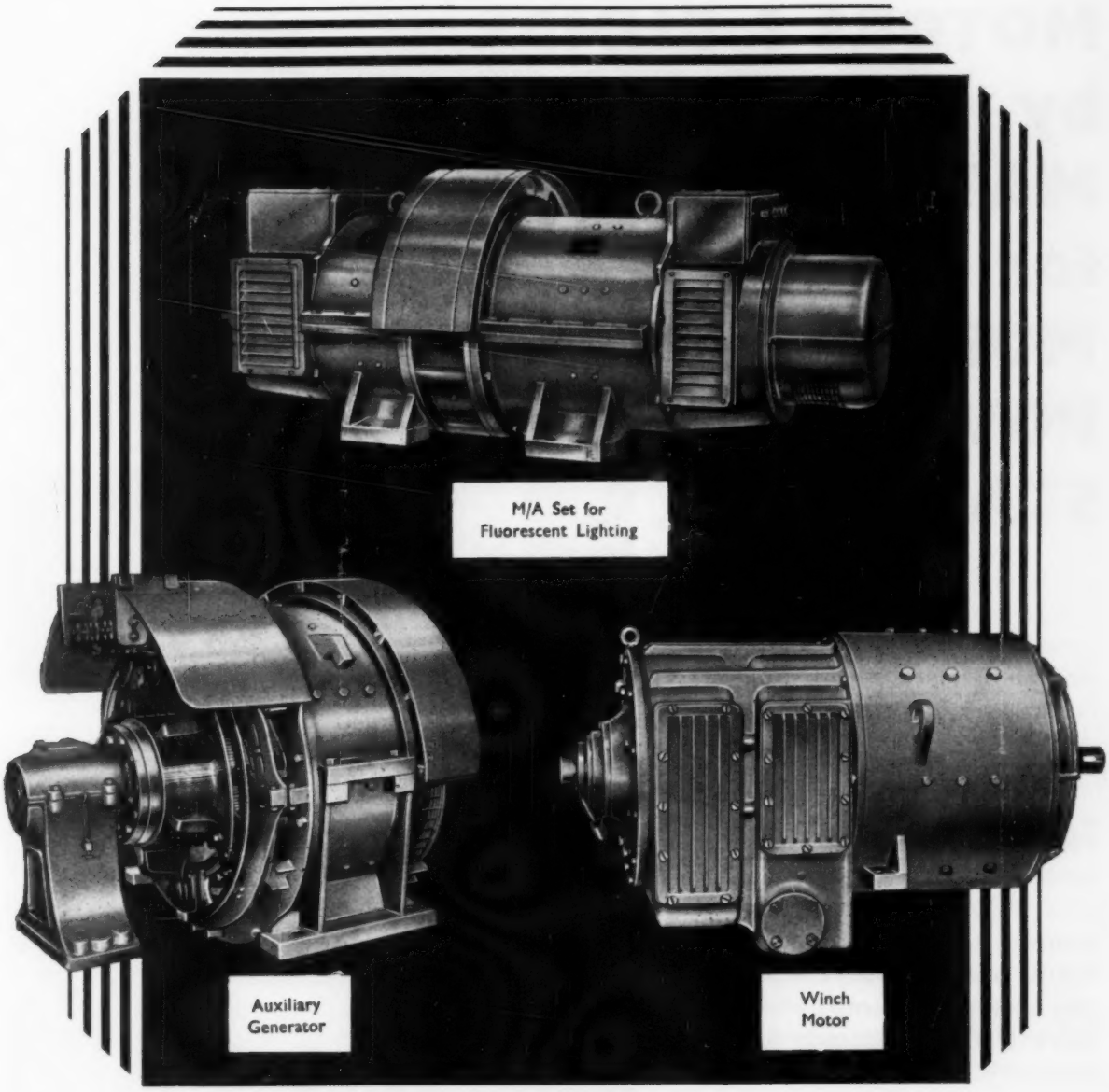

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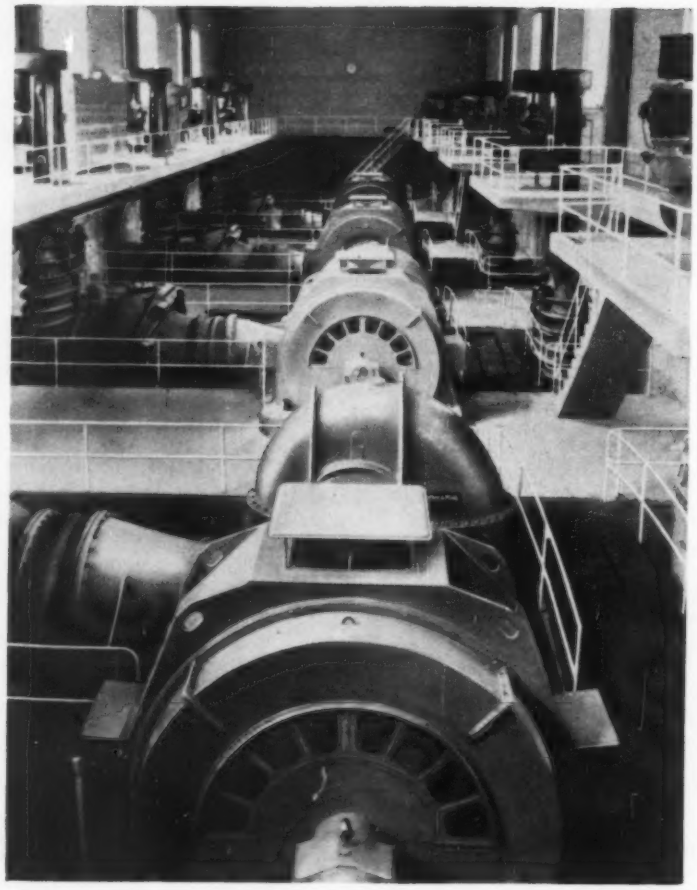

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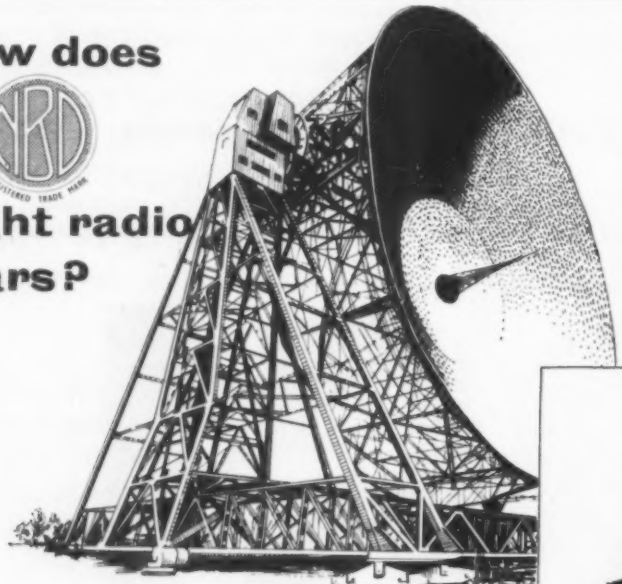

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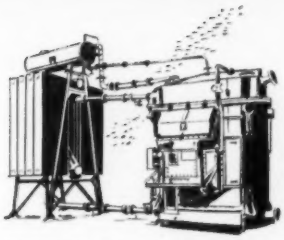

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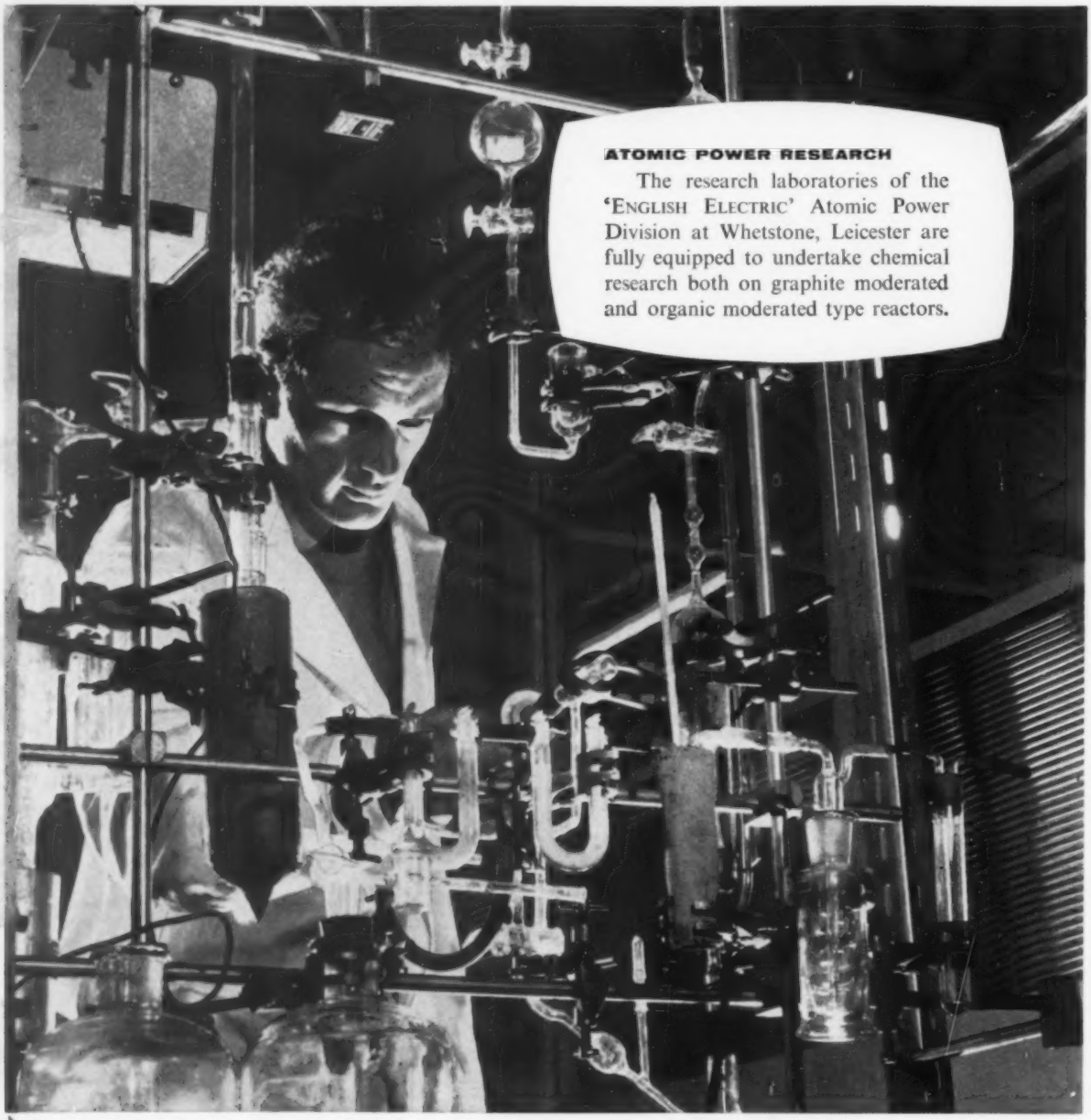

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